Foundations of AIR POWER

Bob Monahan

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AIR FORCE R.O.T.C.

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MAXWELL AIR FORCE BASE, ALABAMA

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For the Commandant:

OFFICIAL

William E. McEntire,
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The Idea of Air Power

THERE IS ONLY ONE THING more fantastic than modern air power. That is tomorrow's air power. The United States Air Force, which has always been a rather unbelievable operation, has made the impossible into tradition, and can only justify its existence by continuously incorporating the unimaginable into routine procedure.

We are no longer amazed at such marvels as mid-air refueling of giant jet bombers. It does not even occur to us to doubt that, right at this moment, there is an aircraft crew quietly busy at the controls of a vehicle flying faster than sound. Or that young men in blue uniforms are sitting in classrooms listening to lectures on space navigation. Or that Air Force scientists are, right now, checking the instruments of a new rocket designed for exploration still farther out into the solar system.

Those of us in the Air Force have become so accustomed to the rapid change of pace that we have had our sense of wonder numbed—numbed to the point where we accept fantastic and sudden changes without even mild surprise.

Most of us feel incompetent to understand the intricate technical details of these developments, and merely accept the scientist's word for the truth of his pronouncements. We have grown too old for fairy tales, and too sophistocated to enjoy the stage magician. We no longer believe in miracles. Now, modern science provides us with all three, but with a difference. We could disbelieve the fairy tale and still enjoy it. We could applaud the magician, not for his "magic," but for his talent at deceiving us. And in the miracle we could find a reminder of the insignificance of man's knowledge.

But now, if the mathematics professor across the campus should say we can reach Mars in a 20-day flight, or if the newspaper should announce that Air Force contracts have been awarded to build a thermonuclear rocket, or if a foreign power should claim to have sampled the atmosphere of Venus with a rocket which is also capable of annihilating all of Illinois—now we simply believe it. We may be shocked, but we do not wonder. We may yawn or we may panic, but we do not doubt.

The situation presents an unprecedented challenge. The man who aspires to leadership in tomorrow's civil or military affairs must be adaptable without instability. He must accept startling developments with flexibility but without gullibility. He must constantly remold his decisions to the changing framework of the scientific facts, but must never allow his technological ignorance to rob him of his initiative.

Progress and change are no longer limited so much by technical know-how or production capabilities, but principally by our habits, our mental rigidity, our emotional resistance to the new and unknown, and our natural tendency to cling to the old and familiar.

It is no accident that the motto of Air University is Proficimus More Irretenti—Progress Unhindered by Tradition. (An Air Force General of my acquaintance once translated it as, "Stay loose, boy! Stay loose!") However you translate it, it means that nothing is more certain than change, that today is never like yesterday, and that the man who can only stand still, relying solely on past experience and what he learned last year, will be left behind, defeated, obsolete, and useless.

The simplest and yet most striking example of this is the man who clings to the old idea of measuring travel distances in miles. Such a man finds it difficult or impossible to grasp the idea of a world actually made smaller by the modern aircraft and missile. This man will ask the conductor on a train, "How far to Plainsville?" and expect to be answered in minutes—not in miles. Yet he still thinks of Europe as being thousands of miles away rather than a few hundred minutes away. He cannot fully adapt to the fact that, to the traveler, the bomber, and the missile, miles are meaningless. Today, the measuring stick for distance is *time,* and, measured by the clock, the world is rapidly shrinking to neighborhood size.

There are those, too, who are blinded by today's headlines. They read of missiles that fly faster and higher than manned aircraft, and they conclude that the pilot has seen his last days. They do not look ahead to the future results of current research. They do not consider that headlines seldom reflect the on-going daily grind of the scientist and the engineer. This work—the patient dissection of intricate and infinite details—is unspectacular. It isn't "newsworthy." But it is the work that will change everything again tomorrow. It is the work resulting from the idea that, if a missile is good, a missile with a man in it is better. Or perhaps—who knows—something else is better yet.

A book such as this is mere history. Even as it is written, it becomes obsolete. As you read it, you must constantly remind yourself that what is said here is only a starting place. It is where we are going that is important, and how fast.

Remind yourself, from time to time, that there are millions of people alive today who were college freshmen before any man had ever flown in a controlled, self-powered aircraft. In hardly more than a half century, aviation has progressed from Orville Wright's 12-second flight to 2,000 m. p. h. jet-propelled aircraft and rockets capable of reaching the moon. Can you stretch your imagination enough to conceive what military and civil aviation will be like 50 years from now—or even by the time you are 40 years old?

You may be a traveler to the moon, an air officer on a satellite in the depths of space, or a civilian leader who helps promote such operations. You may commute from home to a job hundreds of miles away in your own aircraft, or in a rocket-propelled air-bus. You may mail a letter from Los Angeles to London and have it delivered the same day. You will be a responsible citizen on a planet so small that no spot on its surface is more than a few short hours—perhaps minutes—from any other.

The fabulous speed and range of modern air and space craft have placed our allies right on our front porch, and our enemies right at the back window.

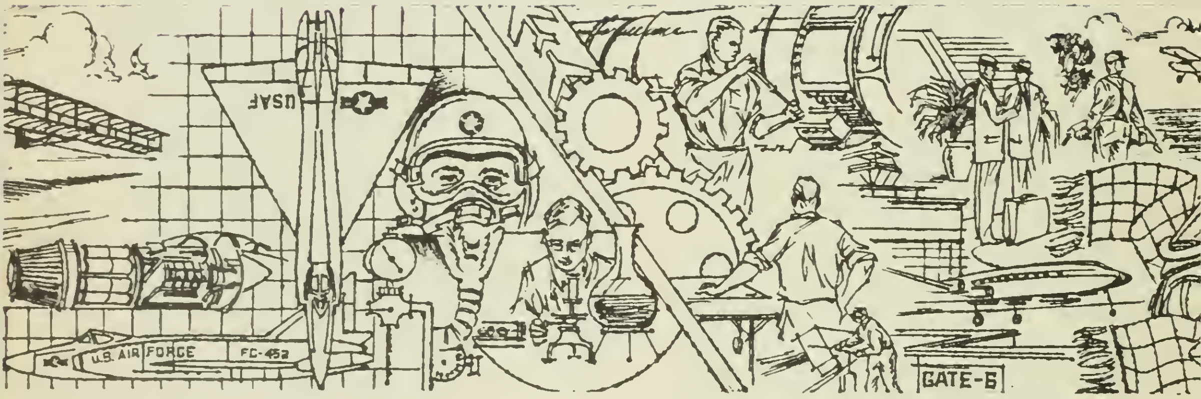
Can we fully grasp the significance of artificial satellies, of space-traveling ballistic missiles, and of man-carrying rocket ships, and yet continue to use the old terms: aircraft, aviation, air science, air power, air force, air age? Must we have a separate set of terms—space craft, astronautics, etc.—which would erroneously imply that we are dealing with a completely separate and entirely different kind of phenomenon, with different purposes and different implications? Or must we eventually develop terms which will include both?

The question is not to be taken lightly. The words we use do much to mold our thinking and to determine our capacity for adaptation to the world we live in. But the evolution of language cannot be rushed. We simply must wait for the appropriate terms to come into existence and into general use.

Meanwhile, we are forced to use the old ones. They need not limit our thinking if we are careful to remember that when we say "aircraft," we include those that reach the edges of the atmosphere and go beyond; that when we say "aviation" we include the concept if not the fact of space stations; that when we say "air age" we include the era of the ballistic missile and the artificial satellite and their revolutionary effects on warfare and international relations.

At times, the borderline between fact and conjecture is difficult to discern. It vacillates, of course, from day to day. Such is the air age—an age of headlong change and technological progress. We must keep ourselves flexible enough to adapt to it, to change our ideas of military tactics and strategy, our ideas of distance and of time, our ideas of international relations and diplomacy—our ideas about the world community. For tomorrow will be different. Only by preparing ourselves for tomorrow can we claim to have made proper use of today.

T. C. Rogers,
Major General, USAF,
Commandant.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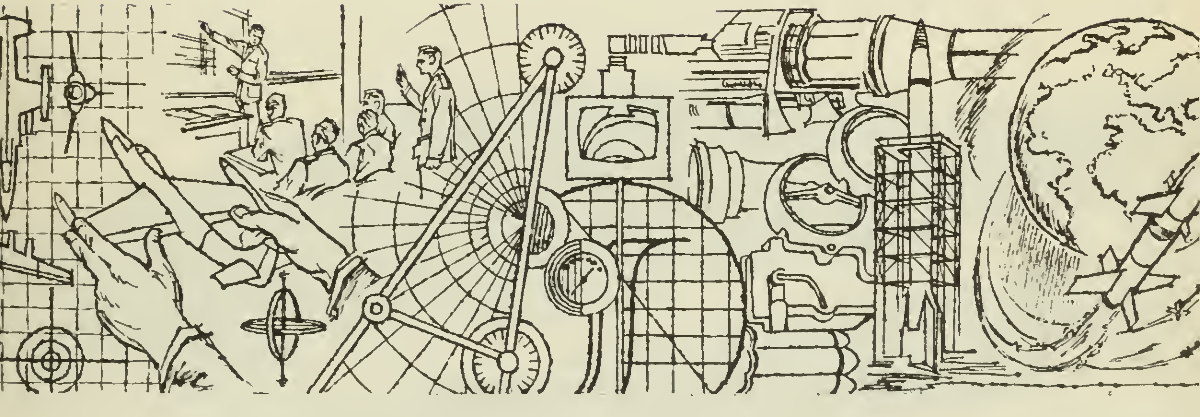
PART ONE

ELEMENTS AND POTENTIALS OF AIR POWER



ART 1

HAPTER 1

Fundamentals of Air Power

MAN'S URGE TO FLY is older than history. It goes back in time to the tale of Icarus, the foolish aviator of Greek mythol-gy, who took to the air with wings of feathers and wax, soared too igh toward the sun, and fell to his death when the wax melted away. wiser student of the art was the Renaissance genius, Leonardo da inci, the first human being to attack the problem of flight in a cientific manner. Da Vinci never flew, and his plans stayed on aper, but in the light of what was known in the 15th century, he nade remarkable progress in getting to the heart of essential aero-autical questions.

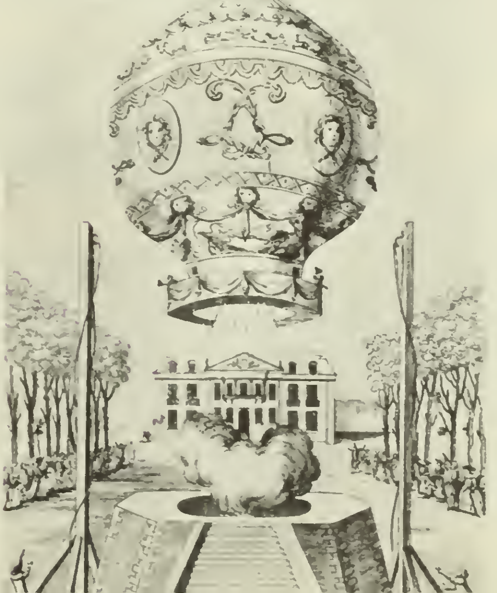
The dream of human flight did not become reality until late in he 18th century. On the fifth day of June 1783, fancy began to urn into fact when a hot air-filled balloon developed by Joseph nd Étienne Montgolfier rose into space. The linen sphere, 111.5 eet in circumference, stayed aloft ten minutes and reached a height f 984 feet.

At almost the same time another French pioneer, the physicist J. A. C. Charles, developed a hydrogen-filled silk balloon, which first went up on the 27th of August 1783. The next month another hot-air balloon built by the Montgolfiers carried two specimens of poultry and a ram into the atmosphere on the first experimental transport flight. Because the animals had withstood the adventure without mishap, a royal prohibition against human ballooning was withdrawn, and on the 15th of October Jean François de Rozier and one of the Montgolfiers became the first men to ascend into the atmosphere. The ascent lasted four and one-half minutes, and the two pioneers of space travel floated up to an altitude of 82 feet. A few days later de Rozier and the Marquis d'Arlandes took off on the first balloon flight in history, a 25-minute journey during which they drifted over the city of Paris.

Sustained, controlled flight still lay beyond the reach of balloonists a century afterward. The year 1871, nevertheless, marked the real beginning of the era of air transport. The Franco-Prussian War was on, and Paris lay under siege. Cut off from the rest of France, the beleaguered Parisians turned to the free balloon as a means of getting over the wall of German power that hemmed them in. Over a period of four months, 64 balloons airlifted four million letters and 88 passengers out of Paris. Only a few of the spheres fell into German hands or went down at sea. Getting mail into Paris was harder than getting it out, but Gallic ingenuity mastered the problem. Each balloon that escaped from Paris had as part of its cargo a number of homing pigeons, which later flew back to the city with return mail.

Start of balloon flight which carried de Rozier and the Marquis d' Arlandes over Paris, November 21, 1783.

U. S. Air Force Photo



The first large-scale transport service did not get underway until 1911. It also used lighter-than-air craft, the remarkable—and controllable—rigid airships designed by Count Ferdinand von Zeppelin. For two years, a fleet of five Zeppelins rode the airways between several German cities. But the service could not pay its way and went into the discard. Though the five dirigibles made no money, they did make the name Zeppelin famous by carrying a total of 24,000 passengers without the loss of one life—a dazzling feat for that primitive era of flight. Yet little came of this and later efforts to harness lighter-than-air craft to civil and military needs. In the First World War, Zeppelin raids on Britain caused alarm but changed nothing. And after the war, the dirigibles of Germany, Britain, and America wrote a common record of promise and disaster that left lighter-than-air flying with a past but no prospects. During the Second World War only a limited number of blimps carrying out a limited patrol assignment saw service.

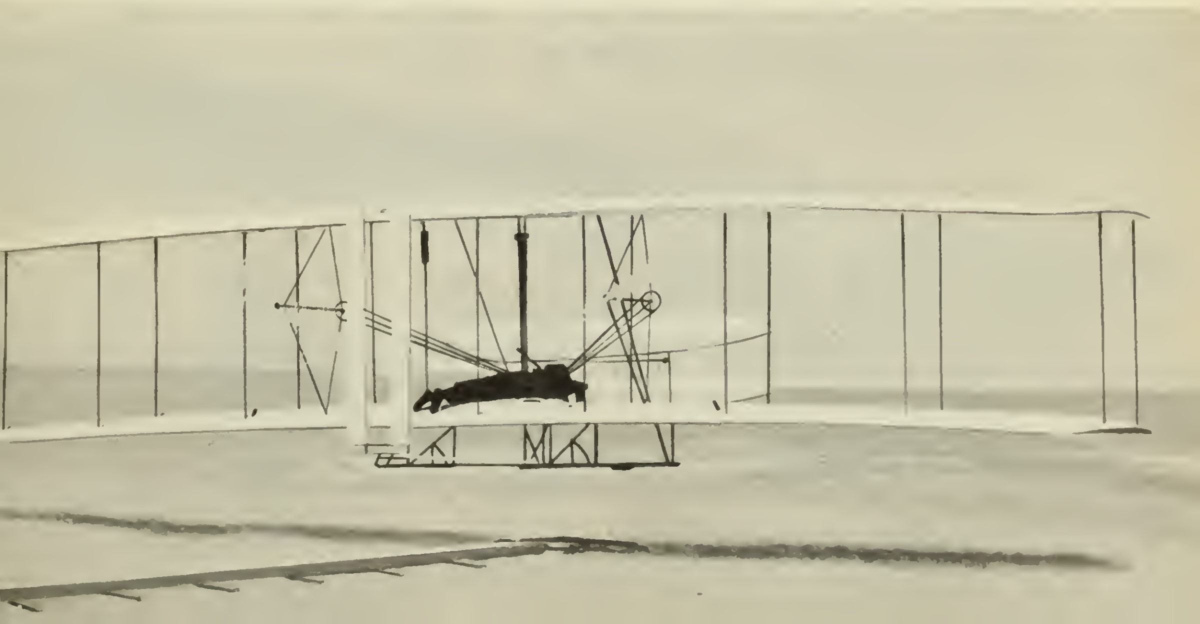
The future belonged to a different kind of vehicle, the heavier-than-air craft. It became possible and then rose swiftly to supremacy because of the cumulative labors of scientists, engineers, and artisans from many countries over a span of centuries. Even a partial list of the trailblazers reads like a *Who's Who* of scientific achievement: Galileo, d'Alembert, Newton, Reynolds, Lord Rayleigh, Prandtl, Bernouilli, Lanchester, Kuta, Joukowski, Froude, Drziewiecki, Lord Kelvin, Eiffel, and the American von Karman. In the field of gliding experiment, Lilienthal, Pilcher, Chanute, Ferber, and the Wright brothers led the way. Henson, Penaud, Kress, Cayley, Stringfellow, Maxim, Langley, and, once again, the Wrights pioneered the development of powered heavier-than-air craft. A fundamental contribution came from Gottlieb Daimler, who invented the high-speed internal combustion engine in 1883. It was this kind of hydrocarbon-fueled motor, with its favorable power-weight ratio, that thrust mankind into a new world. It transformed the bicycle into the motorcycle, the carriage into the automobile, the balloon into the airship, and, most important, the glider into the airplane.

The very mention of the names of some of the men whose minds and hands gave us the heavier-than-air craft underlines how long it took to go from speculation to the reality of flight. The range of interests of these men shows, furthermore, the extent of the knowledge needed to put the airplane into the sky. The road from Galileo's study to the Wright brothers' bicycle shop in Dayton, Ohio, not only took three hundred years to travel but also ran the gamut from the theory of physics to the stench of a balky four-stroke engine. With the passage of time, however, the steady piling-up of abstract and practical knowledge reached a critical point and set off a chain reaction in which aeronautical progress shot ahead at an accelerating speed. The chain reaction still goes on, and it is this process which today makes it easier in the realm of aeronautics to do harder things faster than ever.

The critical point may have come on the 17th of December 1903. At 10:30 that morning, the world suddenly changed. In the presence of five witnesses and his brother Wilbur, Orville Wright took off from the sands of Kitty Hawk, North Carolina, and made history's first sustained, controlled, power-driven flight in a heavier-than-air machine. It lasted 12 seconds. Between 10:30 and noon, Orville and Wilbur took turns aboard the "Flyer." The fourth and final try yielded the best results. The plane flew 852 feet in 59 seconds.

With the barrier broken at last, now all things were possible. During the next two years, the Wrights worked hard at the task of building improvements into their inven-

Orville Wright's historic flight at Kitty Hawk, North Carolina, December 17, 1903.



U. S. Air Force Pho

Monoplane which Louis Blériot of France flew 31 miles across the English Channel in July 1909.

tion and went up well over a hundred times to test their ideas. By 1905 they had moved well ahead and made the first airplane flight of substantial duration—a record run of 24½ miles in 38 minutes and three seconds. Airmen the world over now set out to do what the Wrights had shown to be possible, and many succeeded—Santos-Dumont in 1906, and Voisin, Blériot, Farman, Latham, and S. F. Cody not long after.

For Wilbur and Orville Wright these were years of triumph and gall. They had to learn at first hand that new departures tend to outstrip human understanding. Outside of a small group of aviation enthusiasts, they found it difficult to get a serious hearing either at home or abroad. In France, however, a warm welcome finally awaited them. That country had scored a number of successes with lighter-than-air craft, and attention there soon turned to the
heavier-than-air field, with excellent prog
ress made in 1906 and 1907. The followir
year, Wilbur Wright went to France, prove
that the Wright machine could fly and f
well, and so swept to glory while all Europ
applauded.

The excited interest stirred up by Wilbur
demonstrations marked the beginning of th
international race for air superiority. Ove
night a new idea, air power, took hold
the minds of soldiers, sailors, statesmen, ar
the general public. What one Wright d
in Europe, the other did at home. Th
Wrights had sold an airplane to the Unite
States Army on the 8th of February 190
While Wilbur was in France, Orville bu
the Army machine and then put it throug
its paces at Fort Myer, Virginia, on Se
tember 3d before a crowd of astonishe
spectators. That day's performance wipe
away all doubt at last.

After 1908 the pace of aeronautical a
vance quickened. Overland flights o
after another set new records for speed, al
tude, and length of time aloft. Overwat
flights in their turn wrought perhaps ev
greater changes. In July 1909 Louis Bléri
flew across the English Channel from Ba
raques to the cliffs of Dover. This sing
half-hour hop ended Britain's age-old isol
tion from the European mainland. Than
to this feat and the work of the Voisin

Delagrange, Levavasseur, and others, France surpassed the United States, the birthplace of the airplane, and moved into the lead in aeronautical development. By 1913, however, both Germany and Britain had at least drawn even with France, and in some respects they were forging ahead of her.

AIR POWER AND WAR

Air rivalry soon began to make an impression on military budgets as the great powers hastened to set up aviation sections in their armed forces. The first employment of aircraft in warfare came as early as 1911, in Tripoli and Libya during the Italo-Turkish War. But neither this experiment nor a similar one in the Balkan War of 1912–1913 had any military significance. In the early stages of the First World War the airplane worked almost entirely as a reconnaissance and photographic tool. But before long the fighter interceptor came into being as a means of putting a stop to aerial prying. This led swiftly to a struggle between hostile packs of interceptors for control of the air in which other craft, including bomb-droppers, could operate. By the time the United States plunged into the conflict in April 1917, air war had already assumed its familiar classical form, and the idea of strategic bombardment had begun to move into the foreground of air thinking.

The airplane broke into history at a time when the nations of the world, driven by nationalism and the logic of power politics, were rolling down the slope that led to the First World War. It was inevitable that those same nations should take hold of the new invention and shape it in the image of their power needs. If the dominant theme of the 19th century had been commercial growth, the dominant theme of the first half of the 20th century was war. And the airplane, as a product of the 20th century, quickly reflected the era and became above all else an instrument of destruction.

Air power made its mark as a newcomer to the realm of battle. Within a matter of decades, it became the overlord of that realm and transformed war. But if air power re-made war, war also re-made air power. The harsh demands of conflict squeezed the normal technological progress of a half-century into mere years and sent aeronautical development rocketing ahead. In the advanced industrialized countries of Europe and North America, military necessity brought on an unheard of investment of brains, capital, and equipment in air power; and the dividends reaped in aircraft design and performance matched the rate of investment.

As a result, man has gone in 50-odd years from the 30 mph pace of the Wright "Flyer" at Kitty Hawk to the 350 mph peak performance of bombers in the Second World War, and since then to the upper subsonic,

French Morane Roulier, the first plane used by American aviators in France during World War I.

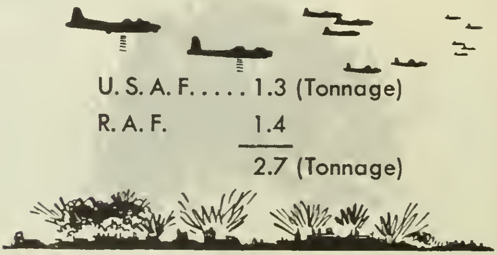
U. S. Air Force Photo

supersonic, and now hypersonic speeds of jet aircraft and guided missiles. From the piston-engine, man has turned to turbojets and rockets for propulsive power. But even though these new power plants are still in the early stages of development, the ceaseless hunt for more and better propulsion has led researchers past the known into the almost uncharted world of nuclear, ionic, and photon engines. Dr. Eugen Sänger of the Stuttgart Research Institute for Physics of Jet Propulsion, in discussing what effect Einstein's shrinkage of time might have on the exploration of the vast abyss of space between our solar system and the nearest stars, has said that photon rockets, rushing far beyond the speed of sound to the speed of light itself, represent the ultimate in jet propulsion.[1] The successful launching of the Russian Earth Satellite in October 1957 meanwhile blazed a pathway toward outer space and thus opened a new era of flight. But even earlier a U. S. Army rocket had reached farther out into the unknown by pushing to a height of 680 miles: and since then every month or week has seen the rise and fall of one record after another. These stellar feats, fraught with promise and hazard alike, only serve to underline the problem of the age: How to draw common benefit instead of common ruin from these runaway products of the technology of modern national states?[2]

Revolutionary developments have not stopped short with the design and performance of air vehicles. Air weapons have also undergone changes drastic enough to alter the face of the earth. Well before the first atomic bomb at one stroke increased firepower 166,567 percent, the gutted cities of Europe testified to the destructiveness of the earlier generation of bombs. Between 1939 and 1945, high explosives and incendiaries ruined a continent and made over the conduct of war. The Germans dropped an unprecedented 70,000 tons of bombs on Britain. But having sowed the wind, they reaped a whirlwind in the form of the 2,000,000 tons of bombs that the Allied Air Forces showered upon Axis-controlled Europe. About half those bombs fell on Germany itself and made a great contribution to the victory of the United Nations. The combination of long-range fighter, long-range bomber, and aerial bomb broke the German Air Force, gave the Allies air superiority, and thus unlocked the door to Western Europe for General Eisenhower's armies. Had the Allies realized the critical nature of the oil and transportation target systems and hit them earlier and harder, the invasion of a prostrate Germany might not have been necessary. This conclusion stems from one of the chief findings of the United States Strategic Bombing Survey:

> The German experience suggests that even a first-class military power—rugged and resilient as Germany was—cannot live long under full-scale and free exploitation of air weapons over the heart of its territory. By the beginning of 1945, before the invasion of the homeland itself, Germany was reaching a state of helplessness. Her

Allied bombing of Axis-controlled Europe.



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[1] Eugen Sänger, "Reaching for the Stars", *The Atlantic,* Vol. 200 (Oct. 1957), pp. 153–55.

[2] For a succinct discussion of this problem, see Quincy Wright, "Aviation and World Politics", *Air Affairs,* Vol. 1 (Sep 1946), pp. 97–108 (reprinted in Air Science 4, Vol. III, Book 1, *Military Aspects of World Political Geography,* pp. 15–22). See also Thorsten V. Kalijarvi, "The Crisis of Mankind", in Thorsten V. Kalijarvi and Associates, *Modern World Politics* (New York, 1953), pp. 3–20.

armament production was falling irretrievably, orderliness in effort was disappearing, and total disruption and disintegration were well along. Her armies were still in the field. But with the impending collapse of the supporting economy, the indications were convincing that they would have to cease fighting—any effective fighting—within a few months. Germany was mortally wounded.

In the case of the other great Axis power, o invasion was necessary and none took lace. Japan had long since lost air su- eriority by 1945, and the bombing and lockade of the last year of the war brought er to her knees so effectively that negotia- ions for surrender were already under way efore atomic bombs fell and months ahead f the planned invasion of Kyushu. The uclear weapons that leveled Hiroshima and Jagasaki in the early days of August 1945 erved, however, as a *coup de grâce*—a final low that put an end to a conflict that might ave dragged on. More than that, those wo primitive nuclear devices revolutionized ir war.

The revolution in air weapons that began n the morning of 6 August 1945 has rushed n without let-up, generating an array of ission and fusion weapons hundreds of times nore lethal than the Hiroshima and Naga- aki bombs.[3] Yet with the tremendous rise n firepower, the weapons have gotten rela- ively smaller and lighter. Fast fighter- ombers like the USAF's Thunderchief can ow carry and deliver atomic explosives. Iumanity has reached the point where one nan in one aircraft can, in an instant, kill great city.

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[3] The hydrogen bomb first developed in 1952 ad an explosive effect of about four to five mil- ion tons of TNT, while the 1954 model had an xplosive effect comparable to that of 14 or 15 nillion tons of TNT. The newest H-bombs are aid to possess an explosive effect comparable to hat of 40 to 50 million tons of TNT. Georg W. 'euchter, *Geschichte des Luftkriegs* (Bonn, 1954), . 380.

U. S. Army Photo

The coupling of these immensely destructive weapons with delivery vehicles as swift as the supersonic jet, the hypersonic jet, and the intercontinental ballistic missile has given the offense in war an incalculable edge over the defense. And the edge is economic, as well as military, for offensive power costs significantly less than defensive power.

THE PRE-EMINENCE OF AIR POWER

Science and technology have transformed warfare in this century, and air forces, as the chief beneficiaries of scientific and technological advance, have played a key role in that transformation. The ways and conditions of war are not what they were only a short while ago. Conflict has become unlimited and three-dimensional. It is no longer an affair involving the clash of armies on land or navies at sea. Air forces have thrust it above the surface of the earth into space. Racing across the endless reaches of the sky, they have brought death and the ravages of war to non-combatants and combatants alike, to those living and working in cities far from the scene of surface battles, as well as to those wearing uniforms.

Death in a modern major war, therefore, can touch civilians as readily as fighting men, and sometimes more so. The combined RAF-USAF night and day assault on Hamburg in July 1943 demonstrated this with terrible effect. The deluge of high explosives and incendiaries set off fire storms that killed and injured more people than the second atomic bomb did at Nagasaki. In 1945 the U. S. Twentieth Air Force bombed and burnt out the hearts of Tokyo (over 7,000,000 population) and other metropolitan centers of Japan, robbed millions of their homes, and caused countless casualties. But these events were only a foretaste of present possibilities. Today a modern air force armed with nuclear and thermonuclear weapons can strike swiftly and suddenly and in minutes or hours leave a nation prostrate. Twenty bombs on twenty cities may be enough to paralyze or smash even a major power's war-making capacity.

Man has thus given substance at last t
the concept of absolute war that grew out o
the world conflict of the French Revolu
tionary era. All can now kill all, and be
cause of this the great, urgent task of th
age has become not only the limiting of wa
but its actual abolition. The 1948 report o
the President's Air Policy Commission pu
the need bluntly and well:

> There was a time when the Unite
> States could tolerate with safety a worl
> in which war was the final way of settlin
> disputes among nations . . . Our ge
> graphical position, our Navy, our indus
> trial capacity, our manpower, and th
> armies, navies, and air forces of nation
> allied or associated with us, protected u
> against direct attack in the two Worl
> Wars . . . But, with the recent revolu
> tion in applied science for destructio
> which is still going on, these safeguar
> are no longer enough.
>
> Our national security must be redefine
> in relation to the facts of modern wa
> Our security includes, as always, winnin
> any war we may get into; but now it i
> cludes more than that. It includes n
> losing the first campaign of the war if th
> loss would mean that the country woul
> be invaded and occupied. It includes n
> having our cities destroyed and our popu
> lation decimated in the process of ou
> winning the first campaign. And furthe
> it includes not having our way of life, an
> particularly our civil liberties, taken fro
> us in preparing for war. *Our nation*
> *security, when we define it in this way, ca*
> *be assured only by the elimination of w*
> *itself.*[4]

But the same report had to face up to th
fact that "the provisions of the United Na
tions Charter for the reduction and regula
tion of armaments have not been fulfille
and unilateral disarmament by the Unite
States is out of the question." The Com
mission then argued that if war should com

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[4] U. S., President's Air Policy Commission, *Su*
vival in the Air Age (Washington, 1948), p.
Italics added.

upon us in spite of our efforts to foster world peace the United States must be ready to efend itself. And for the best military de-ense, the Commission looked to the nation's ir power.

Mr. Thomas K. Finletter and his col-agues on the Commission could see only ne way to achieve relative national secu-ity: the adoption of a policy of arming our-elves so strongly that hostile nations would esitate to attack us and our vital national nterests, and come to grief if they ever did ttack. In the eyes of the Commissioners, nly American air supremacy could deter, or f need be, destroy an aggressor. That over-iding fact pointed to the inescapable conclu-ion that the United States would have to uild its military power *around the air arm.*

A year before the Commission handed in ts report, the United States had at last given quality of status to air power by establish-ng the United States Air Force as an in-lependent service coordinate with the Army nd Navy.[5] Now, the Commission's find-ngs and the pressure of events soon com-ined to make the new service a first among quals. But it took another war, the Korean onflict, to harden ideas into national policy. Not until 1951 did the 143 wing program[6] merge as an accepted minimum require-nent for defending the country's security. With this and later programs came budget-ry acknowledgement of the supremacy of ir power. The air forces had finally come nto their own.

Heavy stress in the 1950's on air might has een a logical development. In the late 940's the United States was able to shield he entire free world from the Russians be-ause of a temporary air-atomic monopoly. That monopoly has gone, and Soviet feats in he fields of aircraft, missile, and nuclear and hermonuclear development have forced this country into a race for survival. The danger is great, and it is growing.

To counter the Russian threat, the United States has had to make a two-pronged effort to build its military strength. The chief deterrent remains our far-reaching offensive air power. But a secondary deterrent has arisen lately in the form of modern defensive air power. Offensive aircraft and rockets promise quick devastation to the aggressor's homeland, while defensive aircraft and rockets give him cause to wonder whether he can attack the United States without the risk of decisive losses and failure. Thus air power, whatever its shape may be, now more than ever provides the basic guaranty of national security.

NATIONAL AIR POWER—PRIMARY AND SECONDARY ELEMENTS

The conditions of this age have lifted military air power to such a position of preeminence that at times it seems to be the whole of air power. It is not. Air power means more than a bomber with bombs, or a rocket with warheads. It embraces these, but also far more. Air power is military and civil. It is airports, air bases, and aircraft carriers. It is the Distant Early Warning Line, and a radar scanner on board a Miami-bound airliner. It is the industry that makes the aircraft; it is the host of other industries that turn out the components and accessories, supply the fuel, and dig up and process the raw materials. Its roots are in Clausewitz, but also in folk bent on living long, quiet lives. It mirrors national strength and weakness—the educational standards attained, ideals professed, values held, morality practiced. And it provides a good index of scientific and technological skill available for the operation of the nation's economy and the support of its security forces. It expresses, in short, all the flaws and glories of an onward-rushing civilization.

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[5] The British had taken the step in 1918, the Germans in 1935.

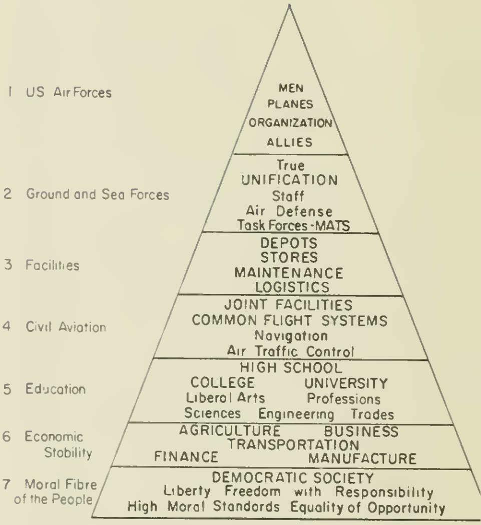
[6] USAF strength has been reprogrammed at ower levels several times since then.

Each nation's ability to use and control the air stems from the aptitudes, talents, training, and aims of its people. Only they can create and sustain air power. Only they can build, operate, and maintain superior air vehicles. An air force in-being may be the supreme embodiment of national air power, but it must come into being before it can embody anything. The making of such a force calls for more than spontaneity and casualness. One observer[7] has said: "Strategy may, if necessary, be improvised; technology, unfortunately, cannot." The planning, design, machining, assembly, testing, flight, and maintenance of modern air vehicles all call for a vast, organized effort by large numbers of highly skilled, highly educated people trained to make the best use of the tools, techniques, and resources of a complex industrialized society.

The foundation of air power is what the people know, what they can do, and what they will do. Without this base on which to build, no superstructure can rise. With it, the superstructure of civil and military aviation can take shape and reach high. Perhaps the easiest way to grasp this multilayered conception of air power is to think in terms of a pyramidal form. The accompanying charts portray what Theodore P. Wright, Vice President of Cornell University and President of Cornell Aeronautica Laboratory, Inc., calls the "national ai power pyramid."

Courtesy of T. P. Wri

THE NATIONA
AIR POWER
PYRAMID



The National Air Power Pyramid.

That pyramid (The National Air Powe Pyramid—Fundamentals) presents in a ordered way the elements of this nation's ai power. At the apex of the pyramid is th United States Air Force, the spearhead o the nation's defense forces and the chief deterrent to aggressors. In the segment belov the apex are the ground and sea forces supporting the air arm. In the third segmen are the facilities that supply and sustain air ground, and sea forces. Next in order come civil aviation, which is of vital importance t our air forces and the totality of our ai power. Underlying all these forces, facilities and services is a stable and efficiently functioning economy, represented near the bottom of the pyramid in the sixth segment Such an economy generates the wherewithal

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[7] Crawford H. Greenewalt, President of E. I. du Pont de Nemours Co., largest chemical firm in the United States.

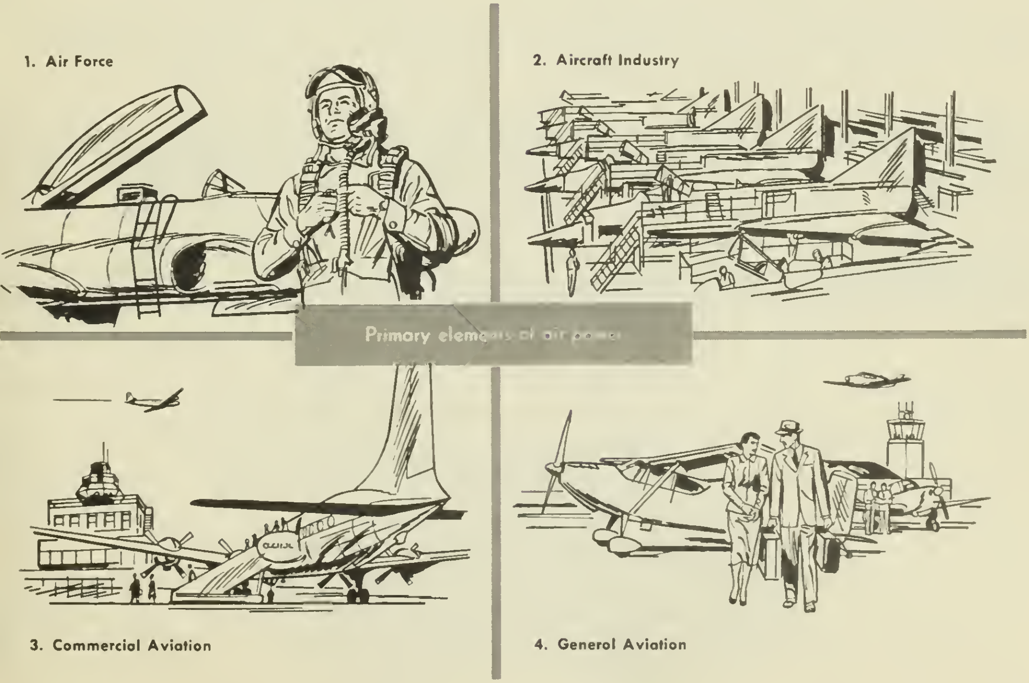
hich makes up the fifth segment. A high evel of education attained in an atmosphere f academic freedom offers the best and peraps only promise of enlightenment and rogress. Without rigorous standards and e right blend of general, technological, and ientific learning, no people can go very far. takes a sure understanding of science and chnology to make complex things; it also kes well-developed civilized values to use em for a good end. Finally, in the last segent at the base, is the moral fibre of the eople, that deepest, innermost source of rength which forms the bed-rock of the hole pyramid.

rimary Elements

The elements that combine to form the tality of air power divide readily, for the urposes of our discussion, into primary and eeded for air research, development, and roduction. Air equipment can be no more dvanced than the nation's economy. And e nation's economy in turn can be no more dvanced than the education of its people,

secondary categories. Into the first category go the elements of air power in-being, the elements that have to do with the here and now of air power. Into the second category go the less obvious longer-term elements that underlie and in time shape air power in-being.

The category of primary elements includes (1) the air force, as well as those surface forces supporting it; (2) the aircraft manufacturing industry; (3) civil airlines and airways; and (4) general aviation. For purposes of definition, the air force is a military force made up of men, equipment, and installations so organized as to carry out military operations in the air. The aircraft industry is the sum of all existing aircraft, missile, and associated manufacturing plants, together with all related engineering and research organizations. Civil aviation spans the two areas of non-military flight: scheduled airline service, and that vital miscellany of air activities called general aviation. Scheduled airline service, the kind of air enterprise most familiar to the average citizen, needs no definition. General aviation,

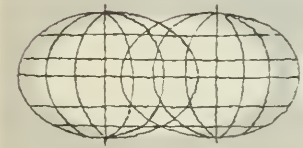

1. Air Force
2. Aircraft Industry
Primary elements of air power
3. Commercial Aviation
4. General Aviation

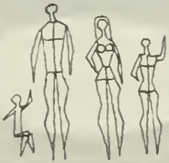
however, does. It is an over-all term for non-scheduled airline flying, private business flying, commercial agricultural flying, patrol and survey flying, instructional flying, and pleasure flying. Apart from flight itself, civil aviation also spans a broad spectrum of aeronautical facilities and functions: airports, airways, maintenance, and radio, radar, meteorological, and other air navigation aids.

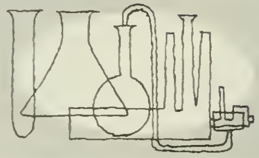
Each one of these primary elements of air power is, in its own way, an essential of incalculable worth. But top place on the list must of course go to the air force, the military force in-being that stands as the first line of the nation's defense. Only it can wage and win a major war today. After it, in descending order of direct value, come the other elements of air power in-being, the aircraft industry and the civil aviation complex. Because of the immediate, critical importance of these primary elements to the very existence of the United States, the remaining chapters of Part I will deal with them in some detail.

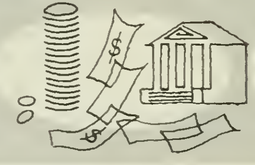
Secondary Elements

Lack of space and time makes it impossible to do more than mention the less immediately critical secondary elements of national air power. These elements, though not generally as quick and sharp as the primary ones in their effect, nevertheless exert a long-term influence that is both fundamental and massive. Air power in-being grows out of them, depends upon them, thrives on their strength or sickens with the contagion of their weakness. They are the key not only to the actuality but also to the potential of a nation's air power. When a else has gone, they can be a vast regenera tive asset for the future. If, for exampl the disasters of war wipe out air power ir being, they can work with surprising sure ness and speed to restore it. Germany an Japan lost everything in the ruin of the Se ond World War, including their air forc and their aircraft industries. Now, less tha 15 years later, each country once again h a military air arm, and an air vehicle i dustry that is well along the road to reco ery. At the same time, the two nations hav resumed their roles as major participants world affairs.


Geography


Population


Science and Industry


National Economy

Political

Though it would be foolish to lose sigh of the life-and-death significance of ai power in-being, it would be at least equall foolish to overlook the elements or facto that shape air power in-being. They sustai what is, and they are the measure of wh may be.

Among the underlying factors that affe a nation's air power position over the yea are the following:

(1) Geography (physical size and co figuration of the country, its physical r sources, its climate).

(2) Population (size, national characte general level of education, adaptability aeronautical requirements).

(3) Level of scientific, technological, an industrial development.

(4) Stability of national economy (sound ness of finance and credit structures, sound ness of budgetary policy, availability of st bilizing governmental controls).

(5) Political strength (stability in gov ernmental policy, rational organization defenses, provision of incentives for air r

earch and development).

These factors exert their influence in a housand ways, but a few examples will sufice to show how they work to foster or hinder the development of national air power. The geography of Switzerland, to ake an extreme case, acts as a drag on the country's air strength. In so small an area here is little call for, and also little room for, highly developed air power. Switzerland's nternal air network is minor; its internaional air operations are well-run but limted; and its small defensive air force must depend on the outside world for aircraft.

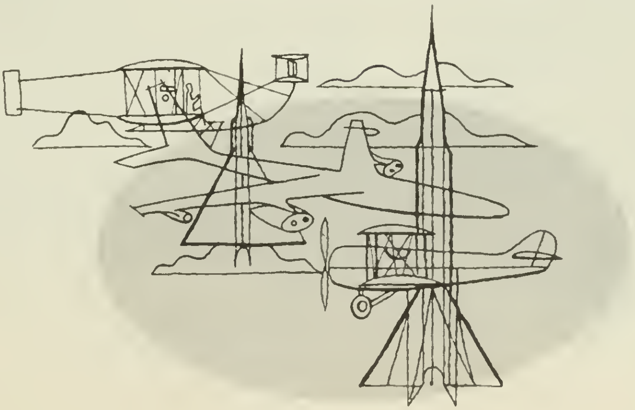
To move to a positive example, the large population of the United States helps to build air strength by furnishing all the fliers, echnicians, maintenance men, builders, scientists, and civil users necessary to large-scale air power. New Zealand's small population, by contrast, simply cannot do as much or support as much.

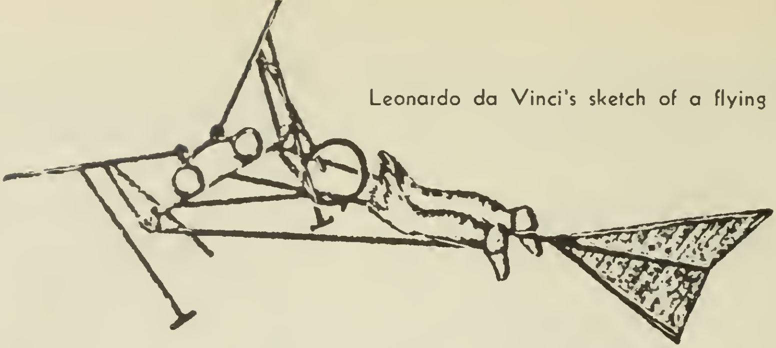
But sheer numbers are not enough. Britain is a major air power. Indonesia, with a much larger population, is not. One major reason for this is that at present the level of scientific, technological, and industrial development is much higher in the old nation than in the new one.

Yet even an advanced country may fail in its efforts to build air power if its economy is unstable. After the First World War, Germany was forbidden to make military aircraft or have an air force. Even without such treaty restrictions, German air power might well not have thrived in the early postwar years because of the inflationary hurricane that laid low the country's economy. Germany's experience in the 1950's, however, provides an instructive contrast. A strong economy, buttressed by sound budgetary and credit policies, has created an almost ideal environment for the new growth of air power in the German Federal Republic. That growth has already begun, and it should go forward rapidly in the coming years.

But nothing avails without political strength. This country and its allies of the free world have fared well in the race for air supremacy only when governmental policy has shown steadiness and consistency, when the organization of national defenses has recognized the proper roles and missions of the individual military services, and when funds and backing have been freely available to spur air research and development. But when policy has weakened into nervous ups and downs, when the organization of the defense establishment has run counter to the facts of military life, and when support for research and development has lagged or faltered, then disaster or near-disaster has followed. The experience of the years after the close of the Second World War illustrates the point painfully and well.

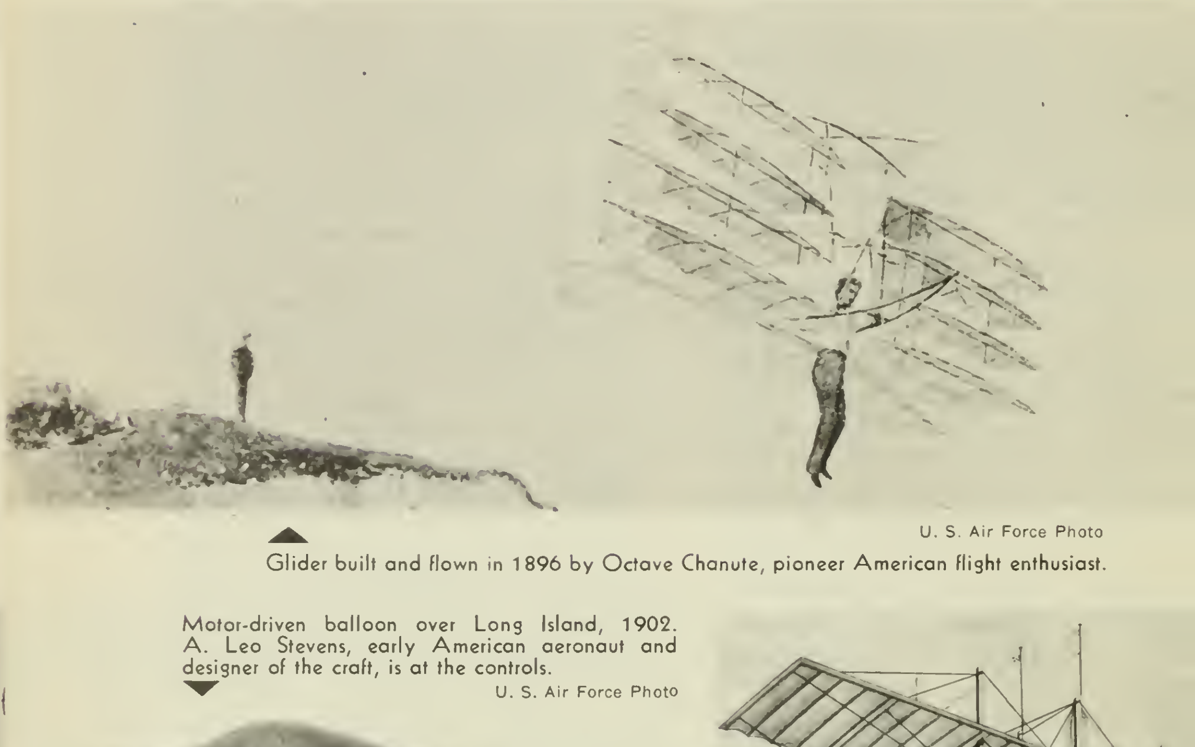
These five underlying factors that affect a nation's air power over the years are constantly at work, constantly defining its limits. Air power in-being bulks large in our consciousness, and it should, but in the long run it will do no more and can do no more for us than our physical condition, human resources, knowledge, productivity, and political policies will allow in the endless struggle for national survival.





Leonardo da Vinci's sketch of a flying machine,
1490.

EARLY FLIGHT VEHICLE

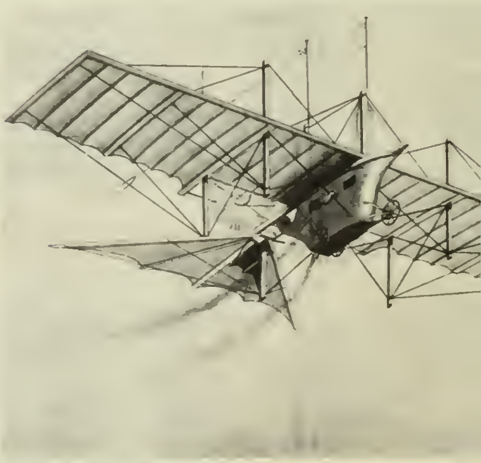


U. S. Air Force Photo

Glider built and flown in 1896 by Octave Chanute, pioneer American flight enthusiast.

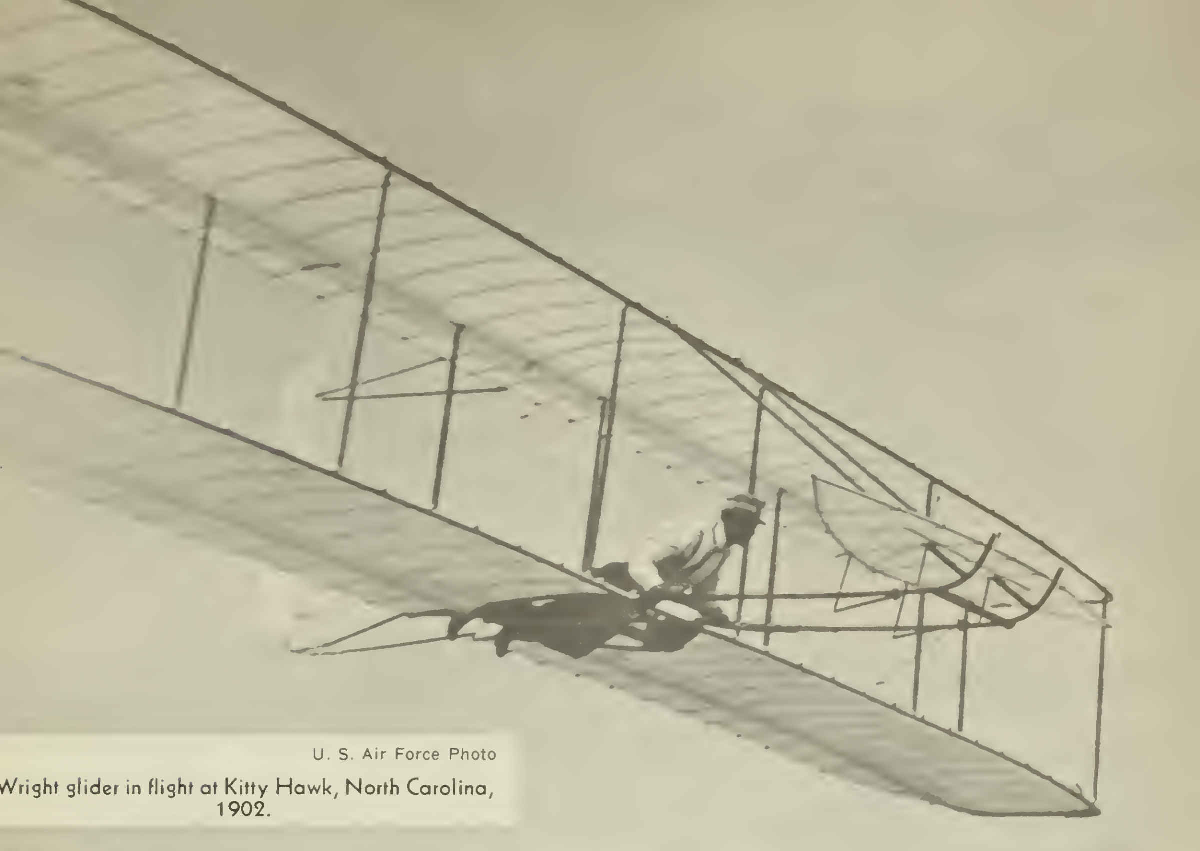
Motor-driven balloon over Long Island, 1902. A. Leo Stevens, early American aeronaut and designer of the craft, is at the controls.

U. S. Air Force Photo



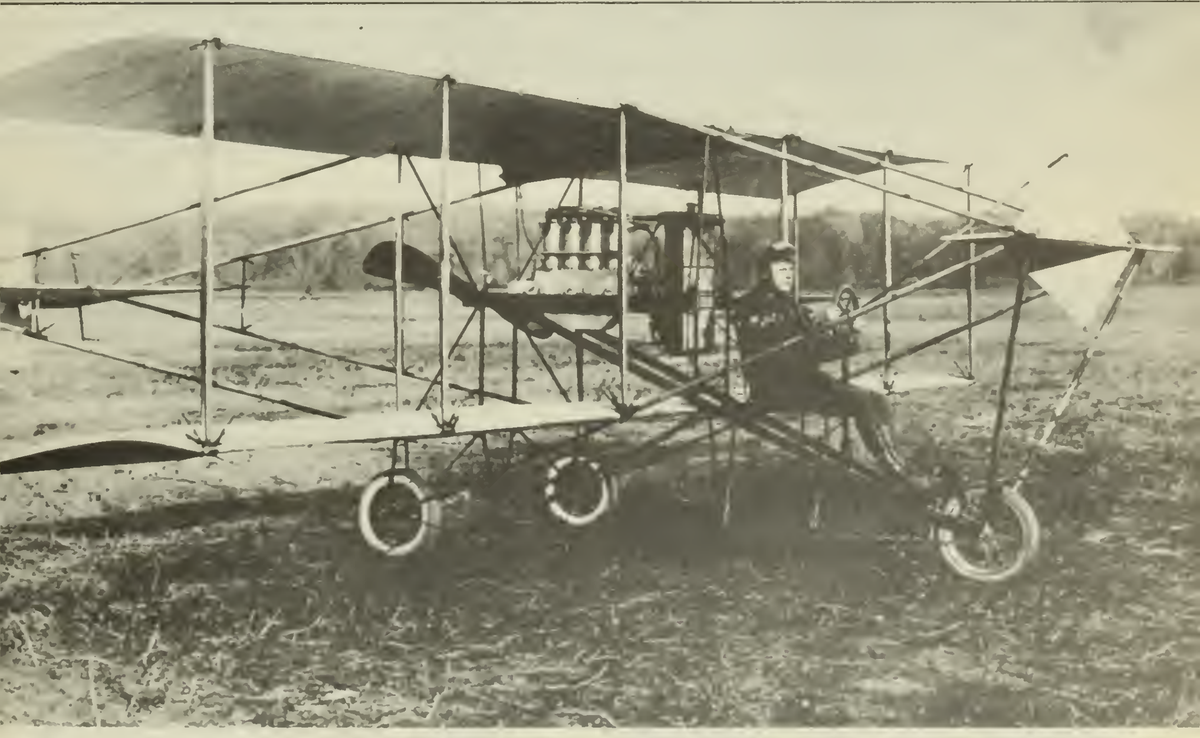
U. S. Air Force Pho

Model of steam-powered airplane built in Englan
by William Henson, 1842. It had a 25 horsepow
steam engine, but never flew.



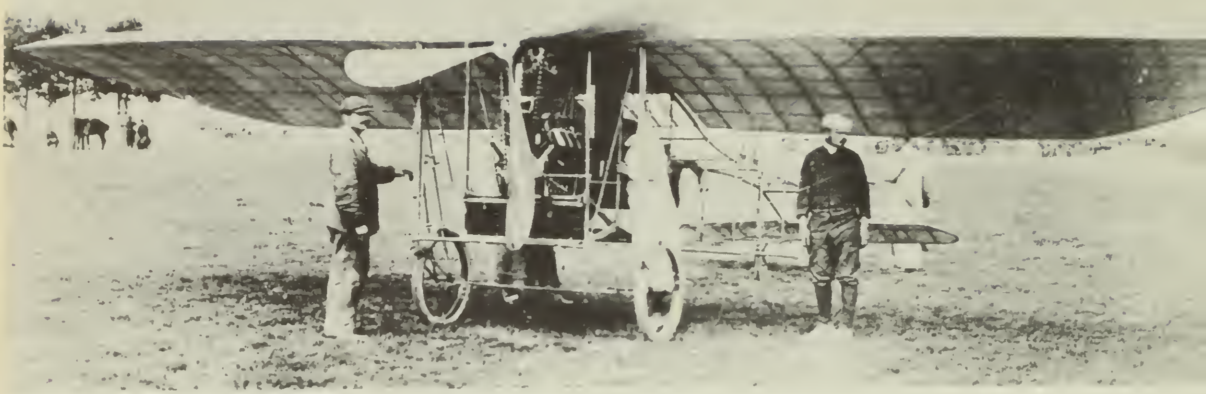
U. S. Air Force Photo

Wright glider in flight at Kitty Hawk, North Carolina, 1902.



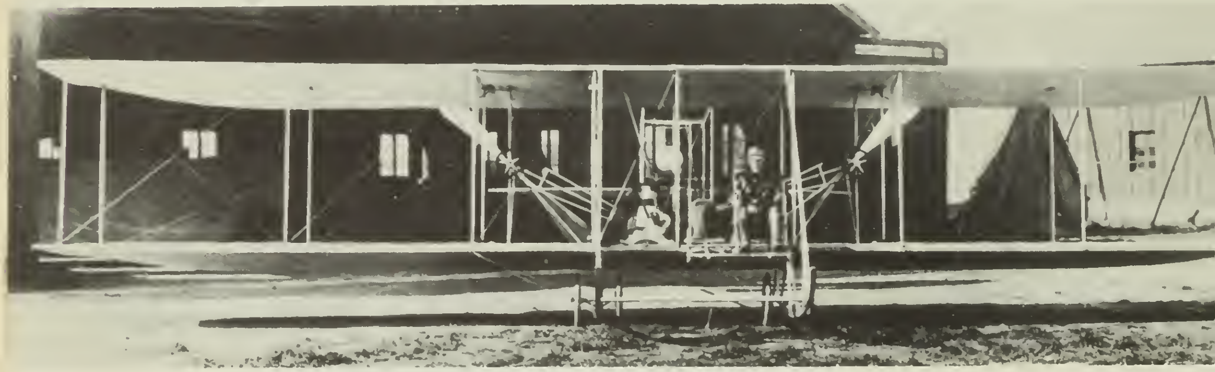
U. S. Air Force Photo

Curtiss pusher training plane at College Park, Maryland, 1911.



U. S. Air Force Photo

Tractor monoplane built by Louis Blériot, 1911.

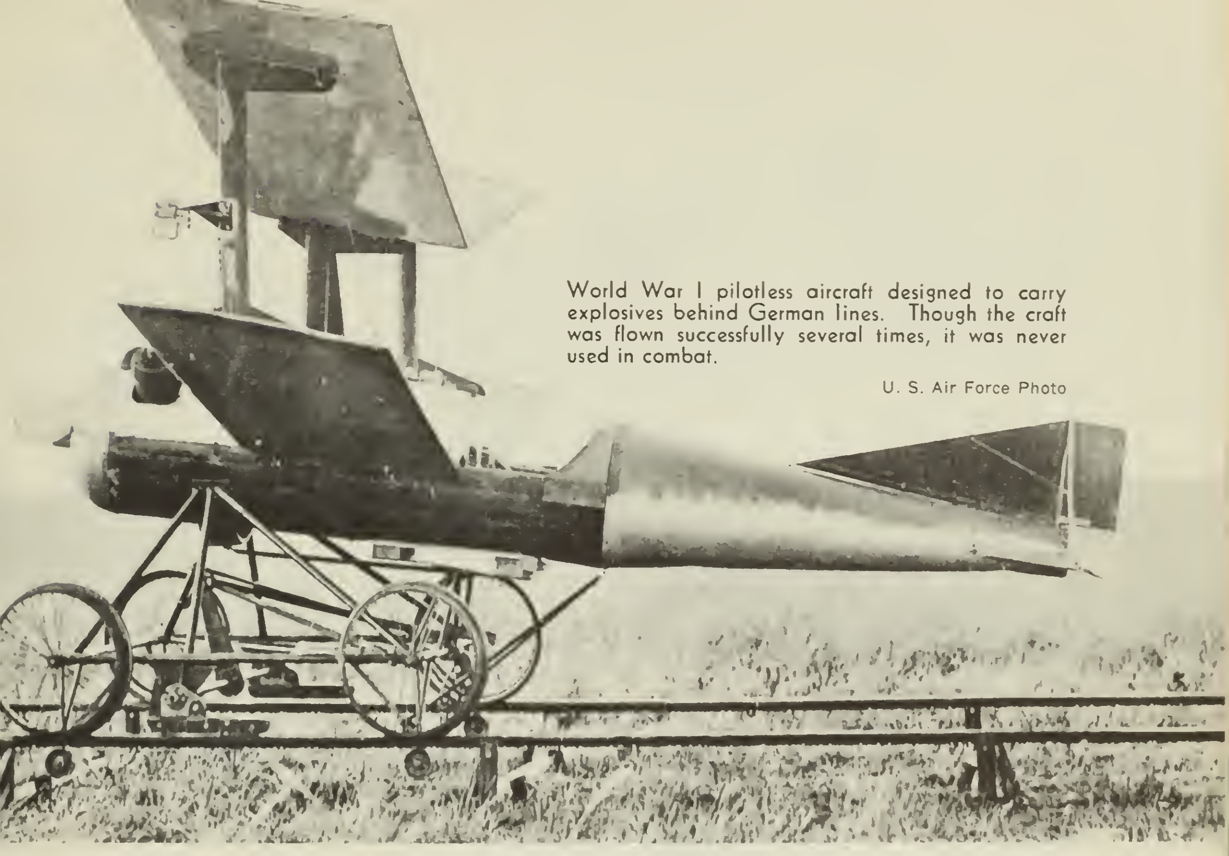


U. S. Air Force Photo

Lt. Henry H. Arnold, who later became the famed General "Hap" Arnold of World War II, at the controls of Wright B airplane at College Park, Maryland, 1911.

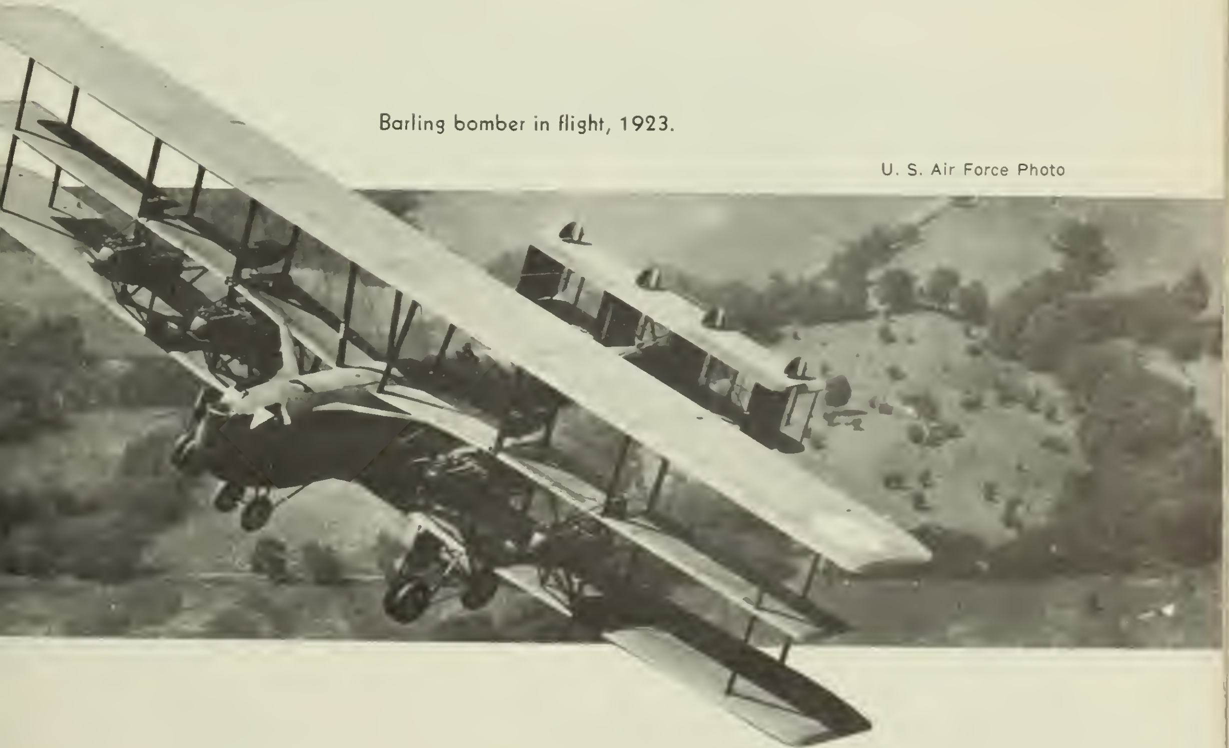
U. S. Air Force Photo

U. S. Air Service Burgess-Wright seaplane at Corregidor Island, P. I., 1913.



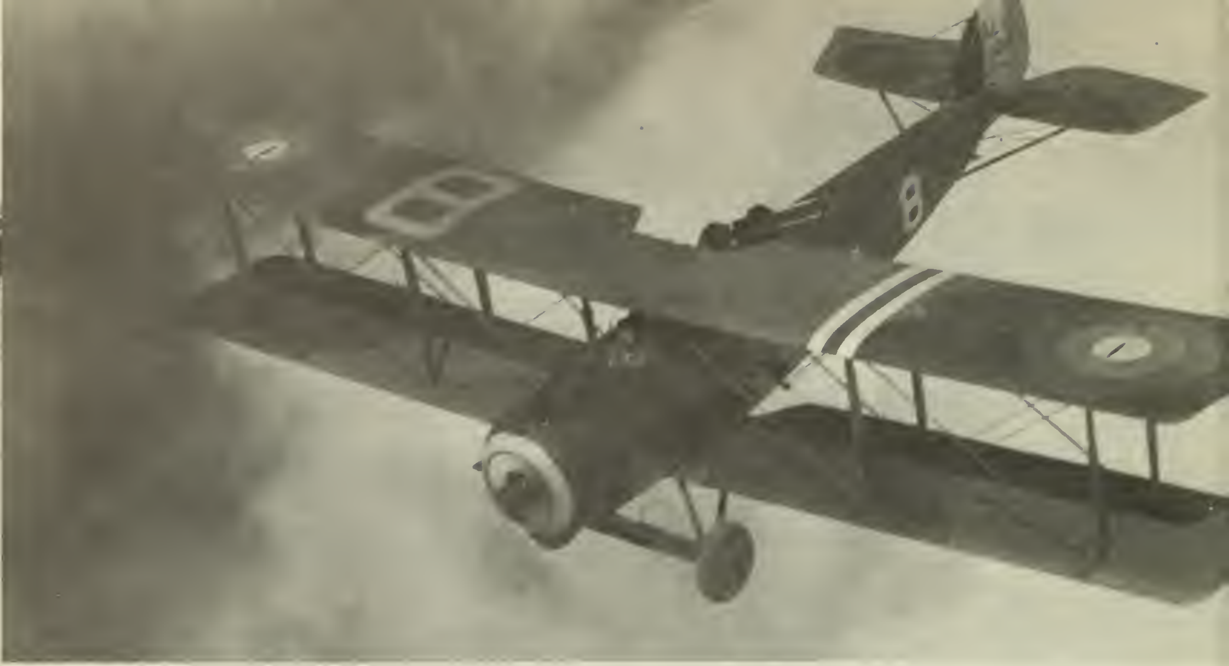
World War I pilotless aircraft designed to carry explosives behind German lines. Though the craft was flown successfully several times, it was never used in combat.

U. S. Air Force Photo



Barling bomber in flight, 1923.

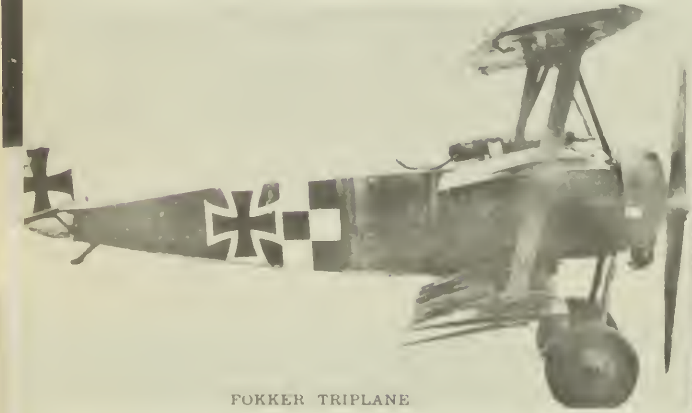
U. S. Air Force Photo



▲ National Archives

World War I British two-seater Salmson observation airplane.

U. S. Air Force Photo



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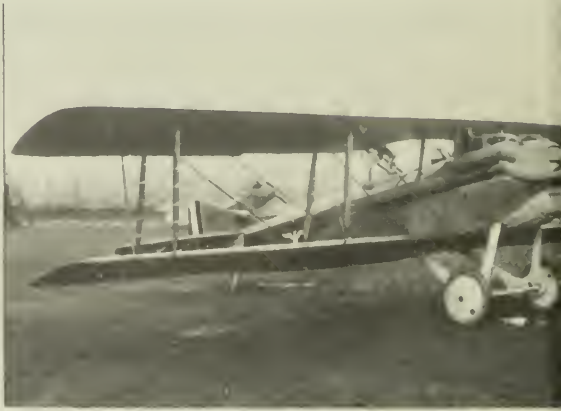

▲
German World War I Fokker triplane.

▲
French built World War I Spad two-seater fighter.

French World War I Farman bomber.
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World War I French Morane fighter.
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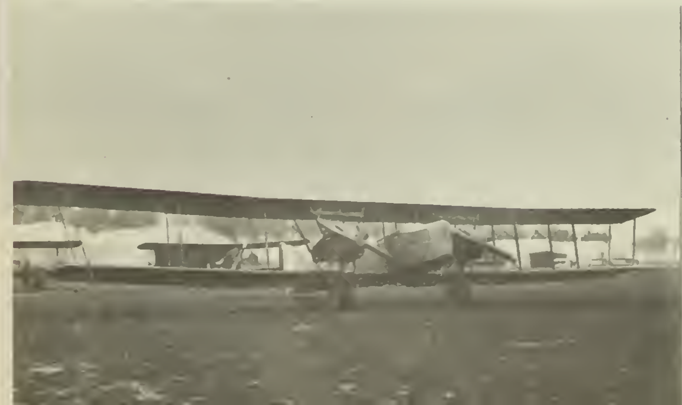
U. S. Air Force Photo



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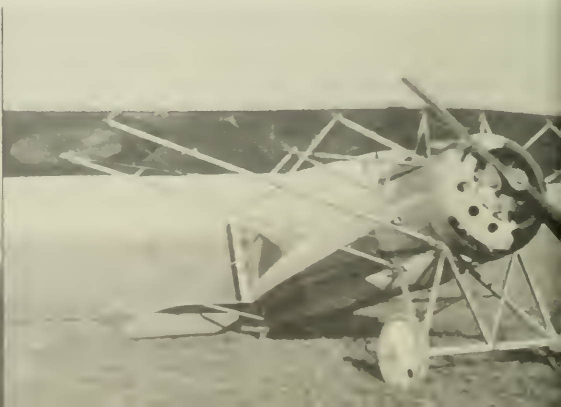
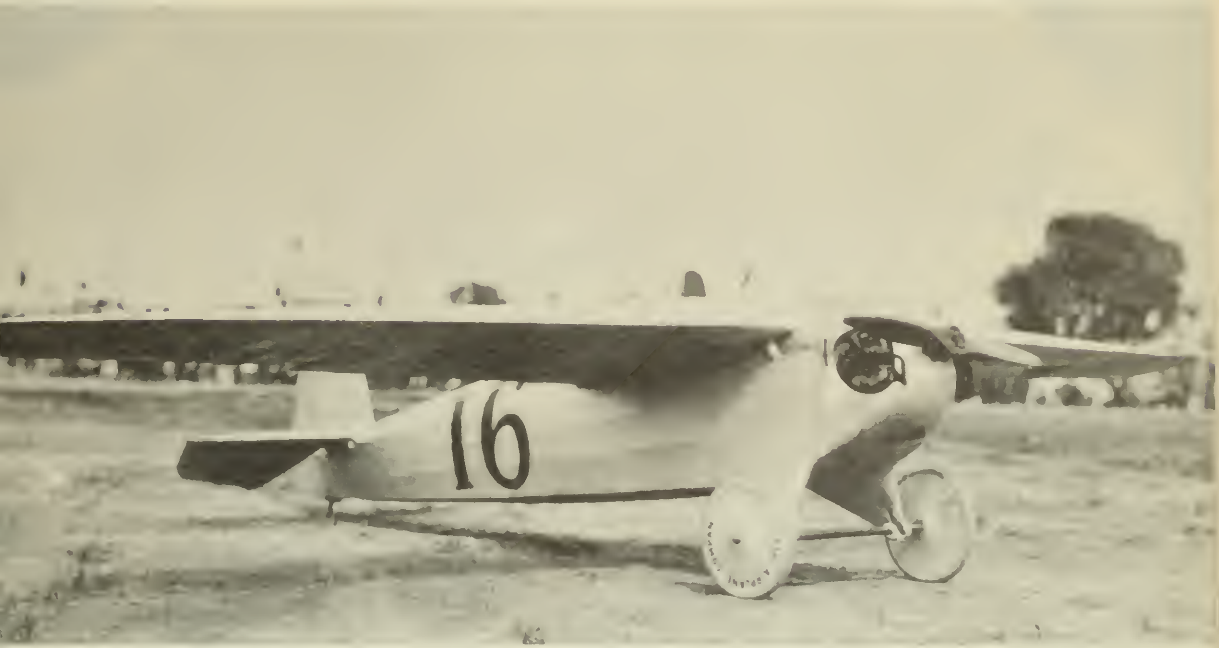
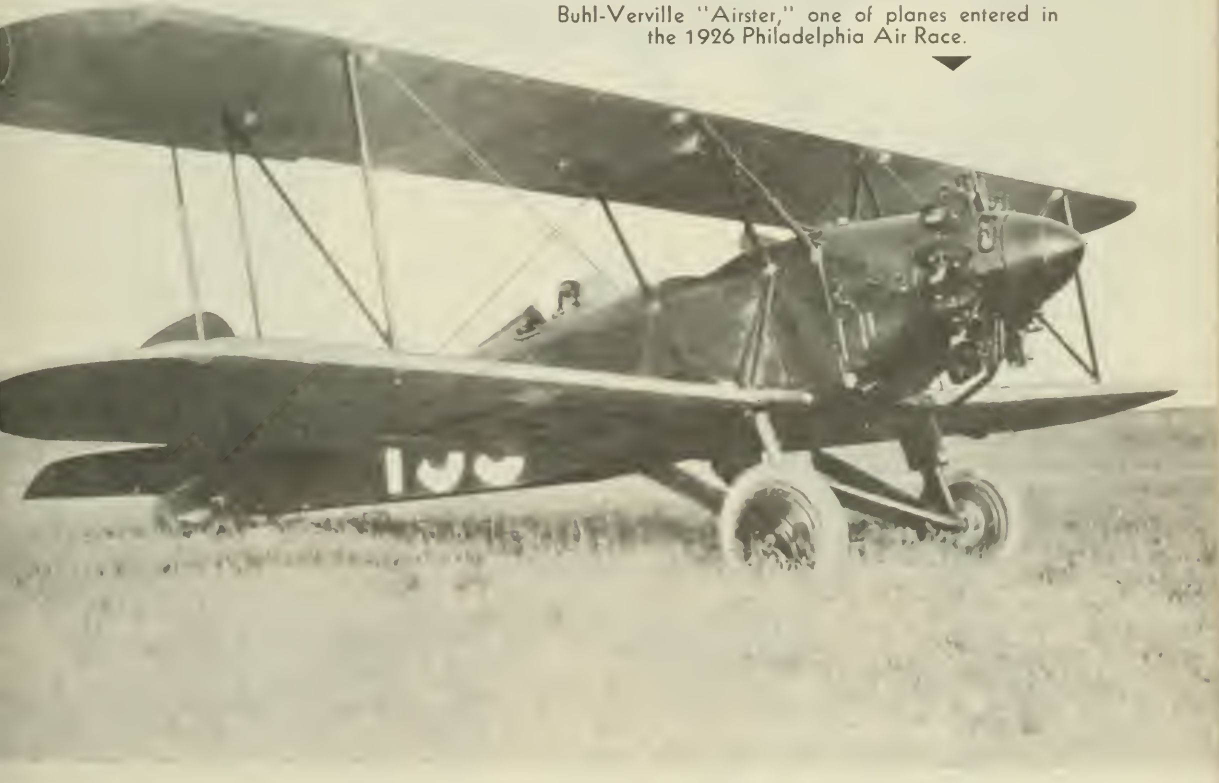


Heath Sport plane winner of 2d place in "Scientific American" Trophy Race at Philadelphia, September 1926.

U. S. Air Force Photo



Buhl-Verville "Airster," one of planes entered in the 1926 Philadelphia Air Race.



U S Air Force Photo

ART 1

HAPTER 2

Military Air Power

THE UNITED STATES AIR FORCE DICTIONARY defines military air power as "that part of a nation's total air power that is military n its character."[1] In the harsh language of the struggle for naional survival, it is the edge of the sword of a country's air power. t is not all of air power, but it and it alone deals directly with an nemy. It and it alone can deter him, or thrust home and destroy im.

Making up the military air power of a nation are its air forces. hose air forces may take different shapes, carry out different tasks, nd operate under different commands. They may actually be alled air forces, or they may take their names from the sea and and services that control them. But whatever their labels may be, hey are all air forces. They all belong to the air. They all exeute their missions in it. Added together, they are military air ower.

This chapter deals with military air power in its national forms. All national air forces share the essential characteristic of air power: an ability to transport men, cargo, and weapons above the earth, unhindered by terrestrial objects. But apart from this, they vary radically from one point in time to the next, and from one country to the next. Each national air force is the unique end product of a complex process. It may resemble other air forces, but it can never be the same because it is an expression of the nation it serves, the conditions under which that nation lives, and the qualities that nation has.

A survey of national air forces will show how diverse military air power can be. It will give some idea of the differences that exist not only between hostile air forces, but also between friendly ones. And it will provide, furthermore, a useful gauge for measuring and comparing the air strength available to the communist world and the free world.

SOVIET AIR POWER

In keeping with the principle that it behooves a nation to know its potential enemies and what they can do, first place in this survey goes to Soviet air power. The Russians claim to have built and flown the first airplane. Although this claim is subject to question, like other Russian historical claims, it is a fact that the Russians manifested an early interest in aviation, and were conducting serious aeronautical experiments before the turn of the century. Igor Sikorsky, who in recent years has contributed immensely to American helicopter development, started building airplanes in Russia in 1909. During the First World War, Sikorsky designed and built 75 bombers for the Czar's military forces. The Sikorsky bomber was quite advanced for its time. It had four engines of 220 horsepower each, and was armed with five machine guns, including a tail gun. By the time of the Bolshevik Revolution in 1917, the Russians were turning out approximately 1,000 planes a year themselves and were also purchasing other aircraft from the French and Italians.

Following the Revolution, the Russian aviation industry suffered heavy setbacks. The Bolsheviks were more concerned with political reliability than with technical capabilities. Many aeonautical technicians left the country; others were put to death. Two notable exceptions were Andrei Tupolev, a young mechanical engineer, and Professor N. E. Zhukovski, who had made studies of the theory of flight. These two men persuaded Lenin to preserve and encourage the study of aeronautics in Russia. With Lenin's blessing, Tupolev and Zhukovski founded the Central Aerodynamics and Hydrodynamics Institute (TsAGI) in Moscow in 1918. The school has developed into a training institute for Soviet aircraft designers, and Tupolev has become known as the father of the Soviet aviation industry.

The Treaty of Versailles, signed in 1919, was of tremendous value to Soviet aviation. As a result of this treaty, defeated Germany was left with virtually no aircraft but hundreds of men who could fly or were interested in aeronautics. The Russians and Germans reached secret agreements in 1922, which provided for German technical assistance to the Soviet aircraft industry and aeronautical training of Soviet officers in Germany. These agreements remained in force until Hitler rose to power in 1933. Soviet aircraft designs were progressively improved, and new Soviet designers were trained. At the same time, Soviet factories made various aero-engines under German, French, British, and U. S. licenses. By 1928

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[1] Woodford Agee Heflin, ed., *The United States Air Force Dictionary* (Washington, 1956).

Russia was producing approximately 50 aircraft per month in six factories.

To restore and expand their sagging economy, which had sunk into a condition of chaos following the Revolution, the Soviets created a series of Five Year Plans. The first got under way in 1928 and included a provision for the development of aviation.

The aviation program under the first Five Year Plan succeeded only in part. Production lagged behind the projected target figures, and the quality of the aircraft produced failed to meet the standards which had been envisioned. Confusion and duplication of effort led to the establishment of separate organizations which took over some of the functions of the Central Aerodynamics and Hydrodynamics Institute. These independent agencies concerned themselves largely with increasing the efficiency of power plants, improving the quality of aircraft materials, and developing design staffs at various aircraft factories.

U. S. Air Force Photo

World War I Sikorsky bomber. It had four 220 horsepower engines and was armed with five machine guns, including a tail gun.

U. S. Air Force Photo

Close-up of Sikorsky bomber. Igor Sikorsky, later to become famous as a designer of helicopters in the United States, is the figure at the center.

Stimulated by foreign technical assistance and popular enthusiasm for flying at home, Russian aviation made rapid strides forward. The military hierarchy was quick to appreciate the value of the air weapon, and by 1930 the Soviet Air Force had attained a strength of about 1,000 front line aircraft. But these planes were an odd collection of types, with foreign designs predominating. Hence, the SAF at this time was not entirely capable of sustained combat operations. The foundation for future growth, however, had been firmly laid. Domestic production increased to approximately 2,000 aircraft in 1932; and the aircraft industry came to the point of being able to operate free of outside help. Then came a setback.

On December 1, 1934 Communist Party leader Kirov was assassinated. This set off a two-year purge which brought death or exile to thousands of non-conformists, including a great many high ranking air-minded Soviet officers. The purge was a turning point in Soviet thinking about air power. One of those who disappeared was the chief Soviet air theorist, General Khripin, who advocated the idea of independent air operations and championed the fast long-range bomber. Because of Khripin, Russia built Tupolev-designed four-engined bombers in spite of opposition from the ground forces.

After Khripin's downfall, things changed. Russian air units in Spain during the 1936–1939 Civil War played a support, rather than independent, role. The same thing happened in the Far East. The undeclared Russo-Japanese War along the Mongolian-

Manchurian border was a surface conflict, and the aircraft taking part in it operated according to Army needs. Russian experience in these campaigns and later in the Finnish War appeared to prove that Khripin's theory of the use of aircraft in a strategic role was basically wrong. Bombing activities had been confined almost exclusively to the support of the ground forces, and it seemed likely they would continue to be. The Russians therefore reduced heavy bomber output and confined air doctrine to the problems of ground support operations. The third Five Year Plan, which started in 1938, laid stress on tactical aircraft. This emphasis lasted to the end of the Second World War.

The early air battles that followed the outbreak of war in September 1939 seemed to the Soviet leaders to offer proof enough of the soundness of their doctrine. The victories of the German Luftwaffe in the onslaughts against Poland, Denmark, Norway, the Low Countries, and France were all achievements of tactical air power. The Battle of Britain seemed added proof. It was the Luftwaffe's first attempt to carry out something like an independent strategic air offensive, and it ended in failure.

Germany attacked the Soviet Union in June 1941. At this time the Soviets were producing about 1,000 aircraft per month. Over 5,000 Soviet tactical aircraft were based along the Eastern front. Against this air force the Germans dispatched nearly 3,000 aircraft. The result was near annihilation for the Russians. They could not match the Germans in aircraft performance or pilot skill, and they paid a terrible price for these shortcomings. Soviet losses in the first two months amounted to nearly 5,000 aircraft.

In addition to this catastrophe, the Soviets also faced another: the possible capture or destruction of their aircraft manufacturing industry. To escape this final blow, they worked feverishly to get their machinery to remote cities and towns east of the Ural Mountains, out of the reach of German air might. They came through the crisis successfully. By 1942 production of aircraft returned to pre-war levels, and Lend-Lease aircraft and material began to flow in from the United States and Great Britain.

The fact that the shift of the aircraft industry from vulnerable areas was made to protect it from strategic air operations may have had some impression upon Soviet leaders and recalled to their minds the theories of the purged Khripin. But it was too late to do anything about those theories. Russia was committed to a surface strategy, and any switch to the production of heavy bombers would have robbed the Red Army of the tactical air strength it needed. However, in 1942, a Long Range Flying Command was created. This force, equipped with Pe–8 four-engined bombers, carried out few strategic missions, and with none too impressive results. For the most part the Long Range Flying Command flew in support of partisan groups behind the German lines. During the Battle of Stalingrad, the force turned to the transport of troops and supplies and also had tactical bombing as an added mission. The Soviets approached the U. S. several times for B–17's and B–24's. They did not get any, in part because the Red Air Force had failed to cooperate with the U. S. and British Air Forces, but also because of American doubts about their ability to maintain such aircraft.

In 1943 the Soviet Union swung over to the offensive against Germany, and by 1944 Soviet forces had recaptured enough territory to permit the return of aircraft factories from beyond the Urals. Soviet aircraft production climbed to 40,000 planes, mostly single-engined, in 1944. But that huge output poured into the familiar channel of tactical air operations. The Russians were masters of the art of using air power in support of armies, and they concentrated on this specialty until the end of the war in Europe in May 1945.

After VE-Day, Stalin visited Berlin and saw the great destruction wrought by American and British bombers. While he was considering this, the U. S. dropped atomic bombs on Hiroshima and Nagasaki and forced Japan to surrender. It became immediately apparent to Stalin and the Soviet military leaders that their air doctrine, though adequate for the war just completed, now needed extensive revision. The same was true for their air force in-being.

The first step in the much needed revamping of Soviet air power was the seizure of nearly 80 percent of the German aircraft industry. With the plants themselves came a large number of aeronautical engineers and scientists, plans for turbojet, turboprop, and rocket engines, plus many actual engines of these types and vast quantities of data and material on both operational and experimental missiles. Armed with these spoils of war, as well as their own growing skills, the Soviets at once set about the task of winning superiority in all fields of air operations.

The attainment of this goal involved the full exploitation of all available German technical talent. At the start the process of exploitation took place in East Germany, where jet engines of German design were produced to power Russia's first jet aircraft, the YAK–15, designed by Yakovlev, and the MIG–9, a product of the design team of Mikoyan and Gurevich. But the "catch up" program moved along too slowly to satisfy the Russian leaders. There followed a shakeup in the Red Air Force and the forced removal of the German technicians to Russia. It is estimated that in 1946 approximately 40,000 Germans, including 3,000 top aeronautical experts, were sent to Russia. These specialists took over a wide variety of positions in the Soviet aircraft industry. Working under them as apprentices were trainees from the Soviet technical schools. Before long results began to show. Russian jets went into operational units, and Russian aeronautical developments went on display at the Aviation Day airshows in Moscow. The West was not particularly impressed.

Two things were happening, however, which were destined both to impress and disturb Western military leaders. First, the design team of Mikoyan and Gurevich, after quietly exploring the prospect of a new kind of jet interceptor with radically advanced

U. S. Air Force Photo

Soviet MIG–15 jet fighter. It first appeared at Moscow during the July 1948 Soviet Aviation Day Show. During the Korean War, UN pilots encountered MIG–15's in appreciable numbers over North Korea.

U. S. Air Force Photo

Soviet MIG–15 captured during the Korean War. It s markings have been replaced with those of the United States Air Force.

performance capabilities, produced the MIG–15 with the help of German designs. The MIG–15 first flew in July 1947 but was unsatisfactory because the performance of its engine fell short of combat requirements. No jet power plant then available to the Soviets from their own resources could meet those requirements. At this juncture, a second thing happened. In 1947 Great Britain sold 55 "Derwent V" and "Nene" jet engines to the Soviets. The Nene, developing 4,500 pounds thrust, was quite adequate to power the MIG–15. The Soviets not only accomplished series production of the Nene in little more than a year, but they also improved upon it with the RD–45 engine of 5,000 pounds thrust, and the VK–1 engine with approximately 6,000 pounds thrust. With such engines the MIG–15 now came into wide operational use and opened the way to the development of modern Soviet jet fighters and bombers.

Before this, the pace of Soviet progress in strategic bomber design had already begun to quicken. The impetus came in the form of American B–29's which had suffered damage in raids on Japan and made forced landings in the Soviet Far East. The Russians confiscated the aircraft and turned them over to the designer, Tupolev, who undertook the task of creating a duplicate. Tupolev's translation of the B–29 into its original production breakdown, and the later Soviet production of approximately 1,200 copies, or TU–4's, as the Soviets designated them, were engineering feats of the first magnitude. The TU–4 gave the Soviets a long-range bombing capability. Time alone gave them the operating experience which facilitated the subsequent transition to higher performance jet bombers.

On June 25, 1950 the Korean War began. The North Korean invasion caught the UN ground forces by surprise and pushed them back to a small area around the port of Pusan on the southeast coast. But the UN Air Forces, though limited in strength, had no difficulty in virtually wiping out the

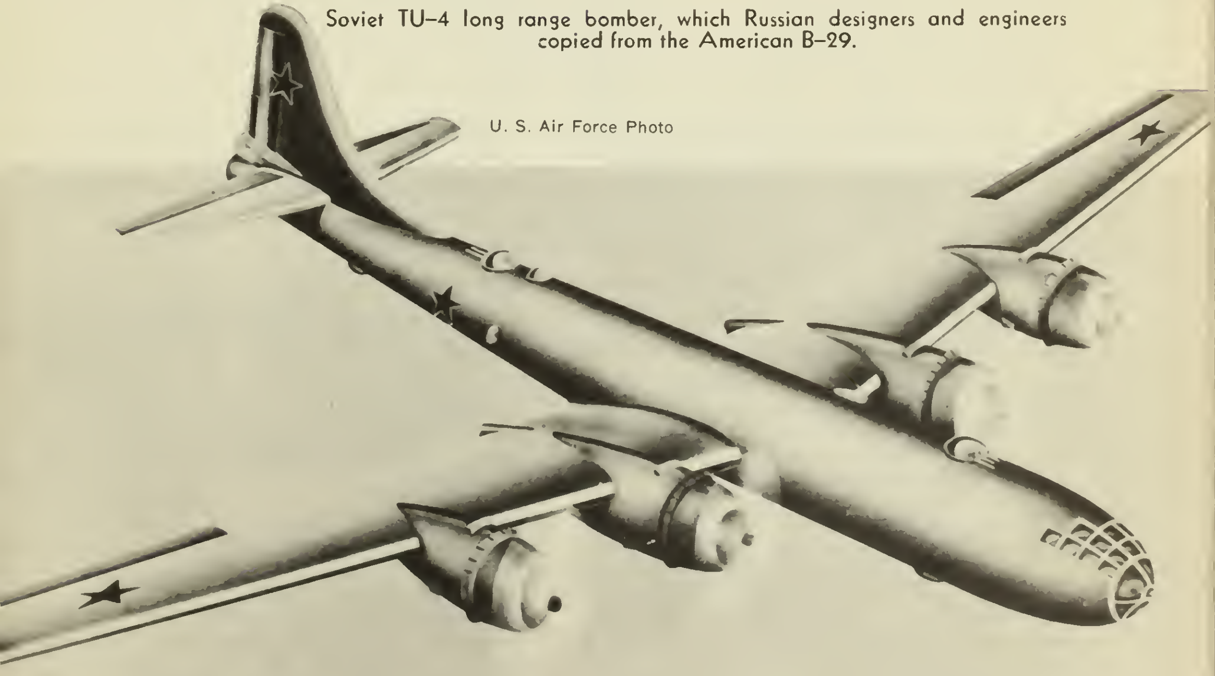
North Korean Air Force, which then consisted entirely of World War II-vintage Soviet aircraft. With the arrival of supplies and reinforcements the UN ground forces were able to take the offensive at the end of summer and quickly sent the North Korean forces reeling back to the Yalu River. At this point Communist China entered the war with "volunteers." Shortly thereafter, UN pilots encountered MIG–15's over North Korea, and MIG–15 radio communications indicated that Russian pilots were at the controls of some of them.

To counter the MIG–15's, the U. S. sent to Korea its best fighter aircraft, the F–86. The MIG–15 was generally considered to be superior, particularly because of its maneuverability and exceptional rate of climb. Nevertheless, for every F–86 lost, 13 MIG–15's went down. This remarkable American success is attributable to the greater training and skill of the USAF pilots, and also to their highly developed teamwork.

Like the Spanish Civil War, the Korean War gave the Soviets the opportunity, without going to war, to develop modern tactics, furnish combat experience to select pilots, and test equipment.

Although the Korean War demonstrated the growing technical competence of the Soviet bloc, it also provided the tremendous shock necessary to reverse the downward trend of American military expenditures. In response to the challenge posed by communist aggression in the Orient, the United States Government soon expanded all its military forces. Under the 143-wing program adopted on 1 October 1951, the USAF was to be more than doubled.[2]

Soviet TU–4 long range bomber, which Russian designers and engineers copied from the American B–29.



U. S. Air Force Photo

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[2] For a brief discussion of the ups and downs of the Air Force expansion program, see Barton Leach, "Obstacles to the Development of American Air Power", *The Annals* of the American Academy of Political and Social Science, Vol. 299 (May 1955).

Soviet Military Organization

The Minister of Defense is one of the more than forty ministers who control every aspect of the economic, political, and military activities of the Soviet Union. He is responsible to the Premier, through the Presidium of the Council of Ministers, and he exercises a centralized authority over ground, naval, and air forces, and their supporting organizations.

Directly under the Minister of Defense is the General Staff. This agency receives through the Minister of Defense the policy decisions of the Communist Party leaders and translates them into specific orders to the military services. The General Staff is organized into a number of planning and administrative sections, the more important ones being Operations, Intelligence, Organization and Mobilization, and Communications. All of the sections are staffed with a mixture of officers from the various branches of the Soviet armed forces.

Two administrators are on an equal level with the General Staff. One is the Chief Inspector, whose title adequately identifies his duties; the other is the Chief Political Administrator. The Chief Political Administrator is particularly important because he has in his charge the continuous political indoctrination and education of Soviet military personnel. His administration has its own channels of communication, and its influence in spreading Communist Party doctrines extends down to the lowest rank and the smallest unit.

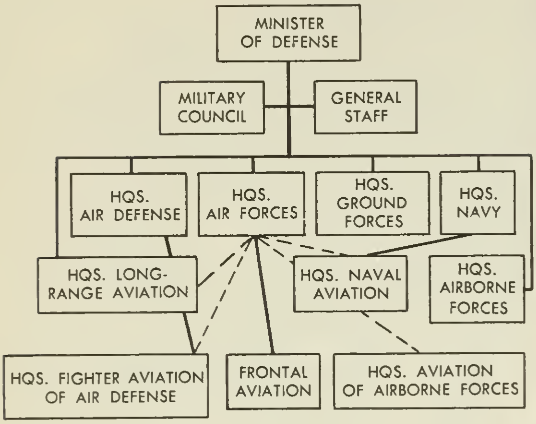
The Soviets have organized their air power into six largely autonomous air forces which, with the exception of the naval air force, all report directly to the General Staff. These six air forces are Long Range Aviation, Fighter Aviation of Air Defense, Air Force of the Soviet Army, Naval Aviation, Aviation of Airborne Forces, and the Civil Air Fleet. Details about the capabilities of these major echelons will come later.

The tactical organization of each air force varies according to its assigned mission. But the administrative and operational subdivisions are generally as follows: The *air army* is the highest echelon operating in the field. It includes three or four air corps with a total aircraft strength ranging from 1,000 to 1,250 and is roughly comparable to a numbered air force in the USAF. The *air corps* is comparable to a USAF air division and consists of three or four air divisions with a total aircraft strength of about 325. The *air division,* comparable to a USAF wing, includes three or four air regiments with a total aircraft strength of approximately 108.

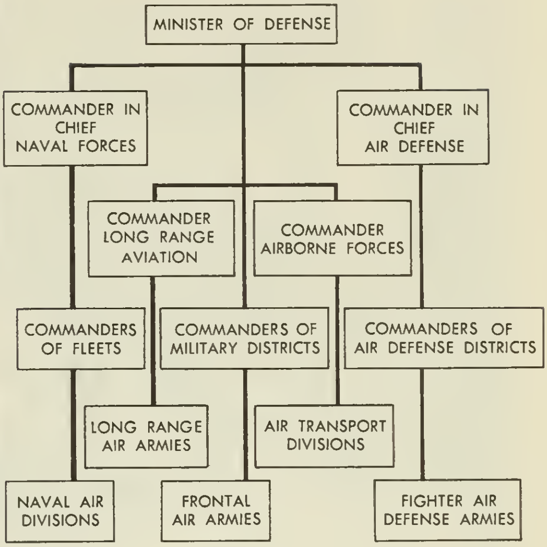
The *air regiment* is the basic combat echelon operating in the field. It resembles a USAF group. Three or four squadrons may comprise one air regiment, and the total aircraft strength is approximately 36, with the number varying according to the mission of the regiment. The *squadron* is the lowest command echelon. It is usually composed of three or four flights of four aircraft each and is similar to the USAF squadron.

The echelons of command within Naval Aviation are the *fleet air force,* which is an equivalent of the air army; the *fleet air division,* which is an equivalent of the Air Division; and the *fleet air regiment,* which is an equivalent of the air regiment. Naval Aviation has no echelon comparable to the air corps.

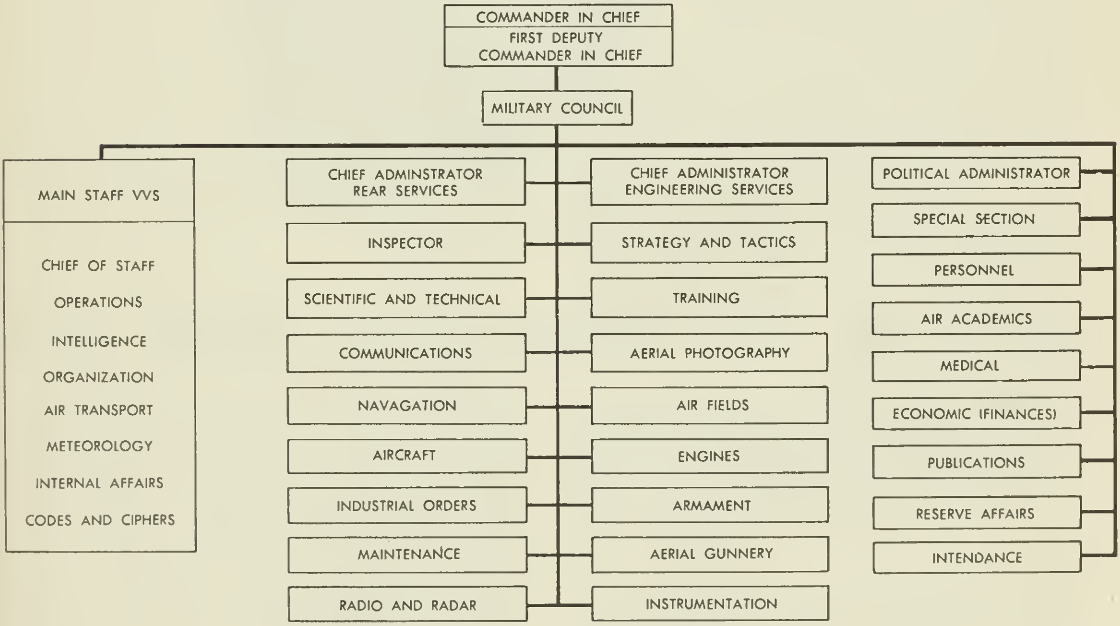
ADMINISTRATIVE STRUCTURE



OPERATIONAL COMMAND


MINISTER OF DEFENSE
COMMANDER IN CHIEF NAVAL FORCES
COMMANDER IN CHIEF AIR DEFENSE
COMMANDER LONG RANGE AVIATION
COMMANDER AIRBORNE FORCES
COMMANDERS OF FLEETS
COMMANDERS OF MILITARY DISTRICTS
COMMANDERS OF AIR DEFENSE DISTRICTS
LONG RANGE AIR ARMIES
AIR TRANSPORT DIVISIONS
NAVAL AIR DIVISIONS
FRONTAL AIR ARMIES
FIGHTER AIR DEFENSE ARMIES

HEADQUARTERS, AIR FORCES (GU-VVS)



Soviet Strategic Capability

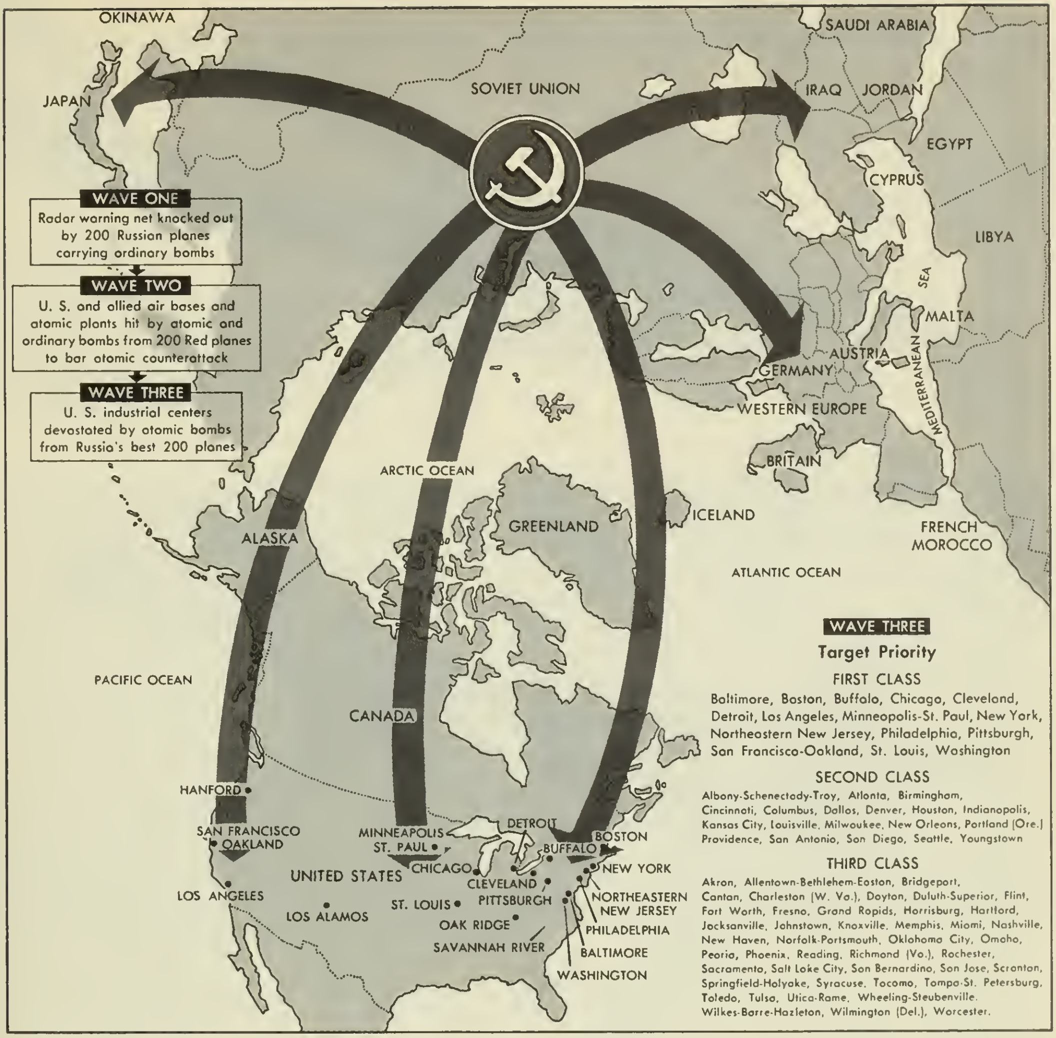
Though the Soviet long-range bombing force came into being early in the Second World War, it played no major role in that conflict, never attained any great size, and worked at tasks that were largely nonstrategic in nature. But in the postwar era it underwent a drastic change. By July 1953, when the Korean War ended, it had grown into an armada of approximately 1,200 TU–4 (or BULL, under the NATO designation system) bombers. These variants of the B–29 were all obsolete, but the Russians were not slow to endow their Long Range Aviation with modern quality as well as quantity. They have since demonstrated an ability to build an advanced, effective strategic bomber and missile force armed with nuclear firepower.

This increasing emphasis on strategic air operations indicates a full Soviet realization of the fact that for the first time the center of power of a potential enemy lies beyond the reach of Soviet ground forces. The Soviet strategic air arm exists, therefore, to do what the Red Army can no longer do. And today Soviet Long Range Aviation is the most significant menace to the security of the United States and the free world. Its over-all strength is no more than 10 percent of the total of about 19,000 first line Soviet aircraft, but the threat it poses to the West is unparalleled.

At the 1954 May Day Air Show in Moscow, observers spotted nine sweptwing jet bombers that looked like the USAF's B–47. This was the West's first view of the TU–16, or BADGER, an aircraft with an estimated weight of over 150,000 pounds, and a speed of about 500 knots. The BADGER is powered by two turbojet engines developing an estimated 18,000 pounds of thrust. It has a range of something like 3,000 nautical miles, which means that it can hit targets in Europe, Asia, and North Africa. Aerial refueling, a technique which the Soviets are developing into an operational tool, could increase this range appreciably. Observers have seen as many as 50 BADGERS in one formation, and the evidence points to the phasing out of the BULL and its replacement in operational units by newer types.

The 1954 Air Show also revealed an even larger new bomber, comparable to the USAF's B–52. This giant, designated BISON, has four jet engines which are probably similar to the pair mounted in the BADGER. The BISON exists for the express purpose of reaching targets in the United States. It probably weighs over 350,000 pounds, has a wing span of 170 feet, and a range of about 5,000 miles at a speed of 500 knots.

The BEAR, an aircraft that made its first showing in April 1955, complete the Soviet long-range bomber inventory of the mid-fifties. It is powered by four turboprop engines developing a total of about 12,000 equivalent shaft horsepower and turning four counterrotating propellers. In size the BEAR stands approximately midway between the BADGER and the BISON. Its speed is remarkably high for a turboprop—about 475 knots—and its range, even without aerial refueling, is an impressive 8,000 nautical miles. Given aerial refueling, before leaving USSR-controlled territory, the BEAR should have a range of 10,000 nautical miles.



WAVE ONE
Radar warning net knocked out by 200 Russian planes carrying ordinary bombs

WAVE TWO
U. S. and allied air bases and atomic plants hit by atomic and ordinary bombs from 200 Red planes to bar atomic counterattack

WAVE THREE
U. S. industrial centers devastated by atomic bombs from Russia's best 200 planes

WAVE THREE

Target Priority

FIRST CLASS

Baltimore, Boston, Buffalo, Chicago, Cleveland, Detroit, Los Angeles, Minneapolis-St. Paul, New York, Northeastern New Jersey, Philadelphia, Pittsburgh, San Francisco-Oakland, St. Louis, Washington

SECOND CLASS

Albany-Schenectady-Troy, Atlanta, Birmingham, Cincinnati, Columbus, Dallas, Denver, Houston, Indianapolis, Kansas City, Louisville, Milwaukee, New Orleans, Portland (Ore.) Providence, San Antonio, San Diego, Seattle, Youngstown

THIRD CLASS

Akron, Allentown-Bethlehem-Easton, Bridgeport, Canton, Charleston (W. Va.), Dayton, Duluth-Superior, Flint, Fort Worth, Fresno, Grand Rapids, Harrisburg, Hartford, Jacksonville, Johnstown, Knoxville, Memphis, Miami, Nashville, New Haven, Norfolk-Portsmouth, Oklahoma City, Omaha, Peoria, Phoenix, Reading, Richmond (Va.), Rochester, Sacramento, Salt Lake City, San Bernardino, San Jose, Scranton, Springfield-Holyoke, Syracuse, Tacoma, Tampa-St. Petersburg, Toledo, Tulsa, Utica-Rome, Wheeling-Steubenville, Wilkes-Barre-Hazleton, Wilmington (Del.), Worcester.

NEWSWEEK Map by Magill. c 1953, NEWSWEEK

HOW RUSSIA MIGHT CRIPPLE U. S. AND ALLIES

How would the Russians start an A-bomb and H-bomb war? No Western expert is so foolhardy as to pretend he can answer that question with any certainty. But in Washington, Jules Menken, British analyst of Soviet affairs, gave his conception (above). He predicted the Reds would launch their long-range bombers against the U. S. and only incidentally against its allies, in three waves:

1. To blot out the radar net, shown schematically above.

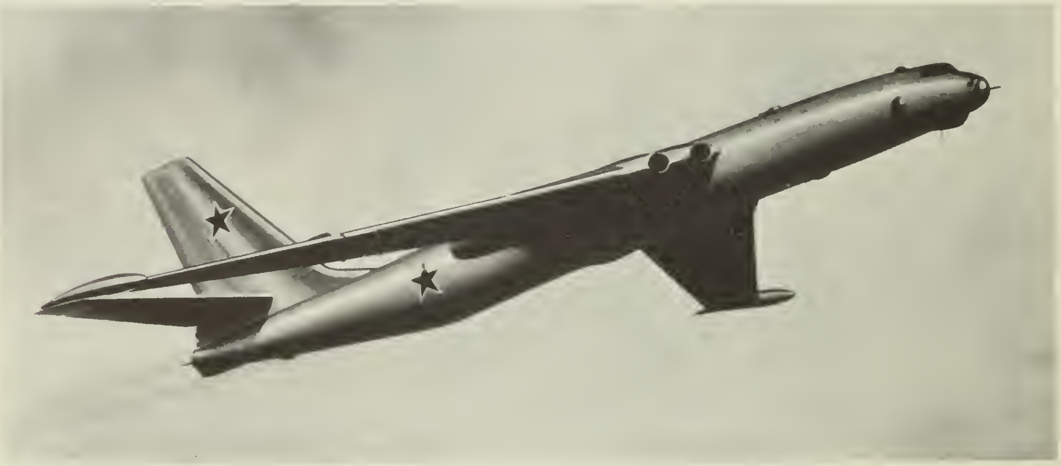
2. To destroy American and allied airfields "from which atomic retaliation . . . could be launched," and also major American atomic facilities. Each airfield symbol represents one or more bases available to the U. S. Strategic Air Command.

3. To devastate some 75 metropolitan areas in the U. S. First priority would be given to the fifteen major centers named and located on the map (each atom-blast symbol represents one or more such targets). Then second-and third-class targets, as listed in the tabulation, would be hit.

Soviet long range BEAR strategic bomber. It is powered by four turbo prop engines and has a speed about 475 knots.

U. S. Air Force Photo

U. S. Air Force Photo



Soviet intercontinental BISON bomber. Comparable to the USAF B–52, this four jet-engine plane has a range about 5,000 nautical miles.

The United States has no counterpart of the BEAR. This aircraft can probably reach most major targets in the U. S. and return to bases within the USSR. It can also serve as a tanker, and, if this should happen, the Soviet potential for two-way intercontinental missions would be appreciably greater.

The faster BISON cannot match the BEAR in range, but its reach is nevertheless intercontinental. That, combined with its speed, makes it probably the most dangerous of the Soviet bombers. From bases in the area of the Kola peninsula, the BISON can strike targets in northeastern U. S. and return home without aerial refueling. From bases in the Chukotski peninsula area, the BISON can carry out two-way missions against the American Northwest, again without aerial refueling. On one-way missions it can penetrate from Soviet bases to a point south of the Panama Canal. And, in spite of its size, it can operate from over 200 airfields within the Soviet Union.

The twin-jet BADGER and the obsolete piston-engined BULL represent a much less immediate threat to the continental United States. Neither aircraft can hope to execute a two-way mission against American cities. But they could probably reach a number of U. S. targets on one-way strikes. This kind of operation would be costly but might well pay huge dividends if the bombloads were nuclear.

On August 26, 1957, the Soviet news agency, Tass, announced that the Soviet Union had successfully launched a "super long-distance inter-continental multi-stage ballistic rocket." The announcement also stated: "The solution of the problem of designing inter-continental ballistic rockets will make it possible to reach remote areas without resorting to a strategic air force, which at the present time is vulnerable to up-to-date means of air defense." This news release was obviously intended for maximum propaganda impact, but there was no disposition on the part of the West to belittle the Soviet achievement. Experts were quick to point out, however, that an appreciable lapse of time is involved between the successful firing of an initial test vehicle and the attainment of even a limited operational capability. But the announcement furnished a clear indication that Soviet progress in rocketry had reached an advanced point. Soviet strategic air power will be progressively transformed as intercontinental missiles gradually take the place of manned aircraft. The end product of the process now beginning will be a transformed and infinitely more powerful Soviet strategic air striking force.

Unless the Soviet Union should find itself in a position either of desperation or limitless atomic plenty, it will probably carry nuclear and thermonuclear weapons only in those air vehicles whose range and speed offer the greatest promise of success. Among such vehicles are the BISON turbojets and, to a lesser extent, the BEAR turboprops described above, plus rocket propelled Intermediate Range Ballistic Missiles, and Intercontinental Ballistic Missiles as they become operationally available. Megaton range[3]

U. S. Air Force Photo

Twin-jet Soviet TU–16 BADGER. Looking like the USAF's B–47, this jet bomber has a range of about 3,000 nautical miles without aerial refueling.

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[3] One megaton is equal to the explosive power of one million tons of TNT. The total weight of bombs dropped on Nazi Germany in six years by the British Royal Air Force and the United States Army Air Forces amounted to approximately 1.4 megatons.

atomic devices of the kind that the Soviets have detonated since 1955 threaten the very life of the United States because the vehicles for delivering them are in-being. The threat will grow as Soviet scientists and engineers couple ever more destructive bombs with infinitely faster, farther-reaching air vehicles.

Soviet Air Defense Capability

Soviet air defense did not attain any outstanding capabilities during the Second World War. This was partly because it never had to. The German Luftwaffe at no time attempted to subject the Soviet Union to the kind of strategic air campaign it waged against Britain in 1940 and 1941. Since the Second World War, however, the Soviets have had the wisdom to undertake a much greater air defense effort. Undoubtedly, the spur of fear has helped them along. For some time now the results of their own atomic tests have given them a firsthand awareness of what nuclear weapons might do to the Soviet Union.

Defense against enemy air attack on the homeland is the responsibility of an autonomous Ministry of Defense administration known as the Air Defense Command, or PVO (from the initials of the Soviet designation, *Protivo-Vozdushnaia Oborona*). The PVO is composed of three major echelons: Fighter Aviation of Air Defense; the Air Observation, Warning, and Communications Service; and Antiaircraft Artillery. These three echelons, working together, stand guard in air defense zones through which enemy bombers must penetrate. The inner zone consists of local areas or air defense districts covering large cities, industrial complexes, and military installations. Moscow, Leningrad, Vladivostok, and probably the Baku oil fields are typical inner zone defense points.

Fighter Aviation of Air Defense has the mission of defending strategic targets through the interception of enemy bombers. It is reportedly an elite force, very thoroughly trained and equipped with the best aircraft. In the mid-fifties its strength approximated 15 percent of the Soviet first line aircraft total and consisted entirely of the following fighter types: MIG–15 (FAGOT), MIG–17 (FRESCO), MIG–19 (FARMER), and YAK–25 (FLASHLIGHT). At that time the MIG–15 was already being replaced by the MIG–17. The MIG–17 has a maximum speed of over 600 knots[4] and a range estimated at 600 nautical miles. Its powerplant is a single jet, probably an improvement of the VK–1. This engine develops approximately 6,000 pounds thrust.

The MIG–19 (FARMER) is a twin-jet, sweptwing aircraft first observed in May 1955. It introduced a new generation in MIG design. It is larger than the MIG–17, and its twin jet engines are encased in the fuselage. Its speed can probably reach 700 knots, which puts it in the supersonic category. The other new aircraft, also seen for the first time in May 1955, is the YAK–25 (FLASHLIGHT), the first Soviet all-weather interceptor. It carries airborne intercept gear, is powered by two jet engines, and can attain a speed of approximately 500 knots. In 1956 the Soviets displayed two new versions of the YAK–25, one with a solid pointed nose suggesting aerodynamic improvement, the other with a glassed-in pointed nose that hinted at a bombing or ground attack role.

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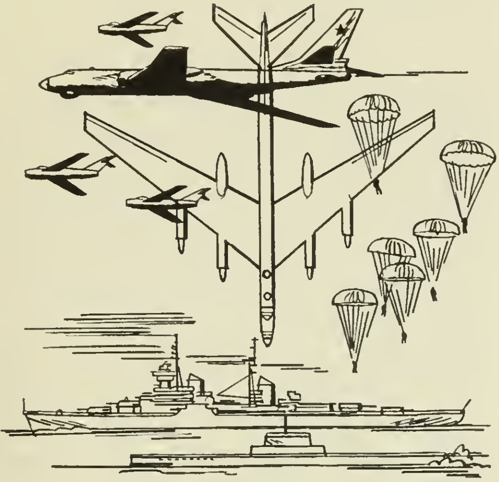
[4] One *knot* equals 1.15 statute miles.

The Air Observation, Warning, and Communications Service controls early warning and ground control intercept radars, searchlights, ground observer nets and identification techniques. Antiaircraft Artillery operates the antiaircraft guns and air defense guided missiles, thus rounding out the Soviet air defense capability.



Soviet Tactical Capabilities

Tactical air power is air power that functions in direct or indirect support of surface operations. In the Soviet Union this support function rests with three forces: Air Force of the Soviet Army, Naval Aviation, and Aviation of Airborne Troops. Together they represent the Soviet Union's normal tactical capability. Standing by, ready to supplement that capability, is the Civil Air Fleet.

The primary mission of the Air Force of the Soviet Army is to support the ground forces. In addition, it doubles as a local defense force, since the areas in which it is based generally lie outside the Soviet Union's regular air defense zones. The Air Force of the Soviet Army has approximately 10,000 first line aircraft, or more than 50 percent of Soviet military air strength, and is organized into an estimated 15 air armies. The aircraft assigned to it include both jet fighters and jet light bombers. The fighters are the MIG–15 and MIG–17, and possibly the MIG–19 and YAK–25 for local air defense purposes. The standard short-range bomber is the IL–28 (BEAGLE), a twin-jet aircraft which first appeared in 1950. It has a maximum speed of approximately 450 knots and a range on the order of 1,000 nautical miles. This level of performance no longer measures up to combat needs, however, and the IL–28 will probably give way soon to more modern aircraft.

The second tactical air component is Naval Aviation. Because the Soviets have no aircraft carriers, this force operates entirely from shore bases. It is assigned to the four fleet commands: Northern, Baltic, Black Sea, and Pacific. Like any naval air arm, it has a wide variety of missions including antisubmarine work, long-range reconnaissance, aerial mining of coastal areas, and destruction of enemy surface and air forces. This last suggests that Naval Aviation, like the Air Force of the Soviet Army, has an air defense responsibility in peripheral or coastal areas. Some of its aircraft are peculiarly naval in character, but many others are orthodox fighters and bombers. Among the specific types identified with Naval Aviation are the MIG–15, MIG–17, the IL–28, the TU–14 (BOSUN), which is a twin-jet bomber similar to the IL–28, and a miscellany of small transports and seaplanes.

The third tactical air component is Aviation of Airborne Troops. Although the Soviets pioneered the technique of airborne operations in the 1930's, they have used it little and to no great effect. The total number of airborne troops today probably exceeds 75,000 men; besides these there may be an equal number of infantrymen trained for combat duties involving air movement. The basic mission of Aviation of Airborne Troops is, of course, cooperation with the ground forces. But to carry out this mission it has less than five percent of the total number of Soviet military aircraft, which suggests that airborne troop training has far outpaced airlift capabilities. Aircraft assigned to airborne work include the LI–2 (CAB), a Soviet version of the American DC–3 (or C–47), which the Russians received in large numbers during the Second World War or built themselves under license; the IL–12 (COACH), a more modern twin-engined transport similar to the Convair; and the IL–14 (CRATE), an improved version of the IL–12. Besides these powered troop carriers the Soviets also have a substantial quantity of gliders whose capacities and characteristics remain somewhat of a mystery.

U. S. Air Force Photo

Soviet IL–12, twin-engine troop carrier.

The final component of Soviet tactical air power is the Civil Air Fleet, or *Aeroflot,* an organization combining both civil and military air transport functions. In wartime its aircraft take up assignments with Long Range Aviation and Aviation of Airborne Troops. In peacetime it provides normal scheduled airline services in the USSR and along a few international routes into adjacent countries. It also operates aircraft for such diverse purposes as crop spraying, forest fire fighting, and meteorological survey. For both scheduled and irregular transport operations, it had an estimated 1,800 planes in the middle 1950's. They included the LI–2, IL–12, IL–14, and the TU–104 (CAMEL), a twin-jet based on the BADGER design, which first appeared in 1955. In 1957, three new transports, each powered by four turboprop engines, made their debut. They are the *Ukraina,* the *Moskva,* or IL–18, which looks something like the American piston-engined DC–7, and the TU–114. Also in 1957, a 4 jet version of the TU–104 appeared, bearing the Soviet designation of TU–110. (See also chapter 5, footnote 19.)

The Civil Air Fleet has a significant place in any over-all estimate of Soviet air power. It not only fills Soviet air transport needs, but also represents a large ready reserve of aircraft and trained men. The Soviets have demonstrated increased efforts to spread their political and economic influence throughout the non-communist world by expansion of international air routes.

Soviet TU–104, CAMEL, twin-jet transport.

U. S. Air Force Photo

The Sino-Soviet Bloc

A complete assessment of Soviet air power must include a consideration of the gross air power of the whole Sino-Soviet bloc, for Soviet air power extends far beyond the boundaries of the Soviet Union itself. In addition to the USSR, the Sino-Soviet bloc embraces the satellite states of Albania, Bulgaria, Czechoslovakia, East Germany, Hungary, Poland, and Rumania in Eastern Europe, and Communist China, North Korea, and North Viet Nam in the Far East. With the exception of Hungary, which lost its air force after the failure of the October 1956 uprising, and North Viet Nam, which has never had one, all of the Sino-Soviet bloc countries can claim some kind of air arm. The Soviet Union of course is far and away the dominant air power of the bloc, but the air strength of its allies and clients is worth noting.

The air forces of the European satellites total approximately 3,000 aircraft. Apart from a few locally-made liaison types, almost all of these aircraft, as well as the supplies and equipment necessary for their operation, originated in the Soviet Union. The list includes such familiar Soviet standbys as the MIG–15, IL–28, LI–2, IL–12, and IL–14. The Soviet Union also furnishes instructors for training purposes. The combat worth and reliability of these air forces are questionable, but, since they are under the control of the Soviet Union, they pose a threat as a supplement to Soviet air power. By themselves, however, they do not, and probably will not, constitute a direct or immediate menace to the United States. They are likely to continue to fall heir to outdated Soviet aircraft and equipment, and there is little chance that they will develop any significant capabilities.

The air forces of Communist China and its small North Korean neighbor also depend on the Soviet Union for aircraft, equipment, and training. But the degree of direct Soviet control and influence is probably substantially less than in Europe. The Chinese Reds and North Koreans between them have about the same quantities and types of aircraft as the European satellites, with one minor difference—a few obsolete TU–4's that the Chinese have acquired. Material similarities aside, the Asian Communist air forces have a markedly greater combat potential than their East European equivalents. One major reason for this is that they have been able to benefit from their years of battle experience in the Korean War.

This has been a generalized analysis of Soviet air power. One central fact emerges from it: the immense threat posed by the 25,000 first line aircraft of the Sino-Soviet bloc. The threat exists now. With the advent of missiles it will become infinitely greater. This is the reality and the prospect, the challenge to which the free world must respond.

FREE WORLD AIR POWER

The foremost air powers of the free world are the United States and the United Kingdom. The two nations are allies of long standing, and their combined air-atomic strength constitutes the major bulwark against communist aggression. In this section, attention will be concentrated not only on the United States Air Force, U. S. Naval Aviation, and U. S. Army Aviation, but also on the United Kingdom's Royal Air Force and the associated air forces of the British Commonwealth of Nations. German air power too will receive some emphasis. After two catastrophic defeats in world wars, Germany is again returning to a position of the first rank. For this reason the rising new West German Luftwaffe, however limited its present size and function, deserves serious consideration. The North Atlantic Treaty Organization will enter the discussion as an entity, with the focus not on the countries belonging to it but rather on the organization itself as a collective instrument for keeping the peace.

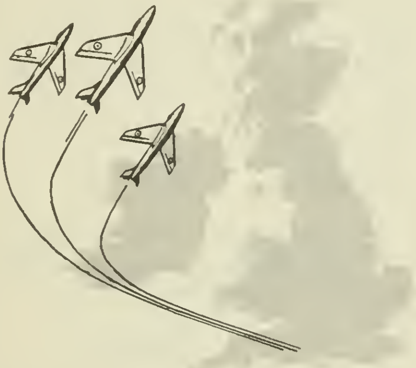
North Atlantic Treaty Organization

The North Atlantic Treaty Organization is fundamentally an association of nations bound together to resist aggression against any of its members. The geographic area covered by NATO is vast. It ranges from the United States and Canada in the New World across the Atlantic and Europe to the eastern frontiers of Turkey. But the organization's main theater of operations is Europe and Asia Minor. There it seeks to prevent war through strength—predominantly air strength in the form of well-trained, well-equipped, mobile fighter and bomber forces flying from a large number of air bases around the Communist European land mass. Any overt act of aggression, such as the advance of Russian armies past the Iron Curtain or a sudden air attack on any member of NATO, will bring instant, violent retaliation from these NATO forces.

But NATO's real value may lie in its meaning rather than in the physical strength of the forces at its immediate disposal. It represents a line drawn across Europe which the Russians know they cannot cross. The Russians see before them the men, guns, and aircraft that make up the NATO shield. But they also see behind that shield the poised might of the RAF's V-Bomber force and the even larger, longer-range U. S. Strategic Air Command. NATO's shield is enough to give the Russians pause. The power behind it serves as a double deterrent.

The North Atlantic Treaty Organization stemmed from the political uncertainty, economic distress, and military nakedness that afflicted Western Europe in the first years after the Second World War. A power vacuum had developed in the wake of German defeat, and statesmen and generals alike were haunted by the thought that the Russians might be tempted to fill it. Western Europe lay wide open, and the Red Army needed only marching orders to roll straight to the Atlantic Ocean. In all of Europe, from Narvik to Bari, and Helmstedt to Land's End, there were barely fifteen understrength army divisions and a miscellany of 1,800 tactical aircraft. The prospect for Free Europe was slavery and ruin, for the United States a decisive shift of the world balance of power in favor of Soviet imperialism. It was under these circumstances that the United States, Canada, Great Britain, France, Italy, Belgium, the Netherlands, Luxemburg, Norway, Denmark, Portugal, and Iceland banded together to sign the North Atlantic Treaty in 1949.[5]

NATO collective defense got under way as a committee operation. But after Red aggression set off the Korean War, it became clear that a much stronger and tighter organization was needed at once. The new phase opened with the arrival in Paris in January 1951 of General of the Army Dwight D. Eisenhower as NATO's first Supreme Allied Commander. Not until then did NATO's forces grow in size and strength. In the mid-1950's, with a total of about 3,000 jet aircraft and 150 jet airfields, together with varied land and sea contingents, the NATO Supreme Commander had at his immediate disposal the wherewithal to make a substantial contribution to deterrence.



The United Kingdom

In 1914 Britain was the island center of the greatest empire the world had ever seen. Sea power had made possible the growth of that empire, and the British knew it. Wherever they went and wherever they looked, they could behold the benefits that had accrued to them from the effective control of the seven seas. But at the same time they were quick to see that the freedom of action, flexibility, and ease of concentration so characteristic of sea power were qualities of air power as well, and to an even greater degree.

More fundamentally, the British were equally quick to realize that Francis Bacon's centuries-old dictum, "he that commands the sea is at great liberty, and may take as much or as little of the war as he will," had been outstripped by time and invention. The first British military aircraft flew on a combat mission in August 1914. Less than four years later, the British Government, urged on by the pressures of war, divorced the Royal Flying Corps from the Army and the Royal Naval Air Service from the Navy, and combined the two into a new service, the Royal Air Force. The birth of the Royal Air Force on April 1, 1918 as a third service, equal to and independent of the older services, amounted to recognition of the fact that war had changed drastically and that air power was or would shortly be the key to supremacy.

During the following two decades the British never withdrew their recognition of the great role that air power would play in national life. The six years of the Second World War provided proof enough of the wisdom of this faith in what the Royal Air Force could do to guard the United Kingdom and then carry the attack to the seat of the enemy's power. Fighter Command turned back a great German air onslaught in the Battle of Britain; later, Bomber Command mounted an infinitely greater strategic air offensive against Germany itself and thereby contributed heavily to the winning of the war.

Today the Royal Air Force holds an unchallenged position as Britain's foremost service. Its primary functions, like those of the United States Air Force, are:

(1) the defense of home territory, bases, communications, and productive capacity against attack.

(2) the destruction of the enemy's national resources and, hence, his capacity to

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[5] Greece, Turkey, and the Federal Republic of Germany (West Germany) became member nations later.

continue the struggle.

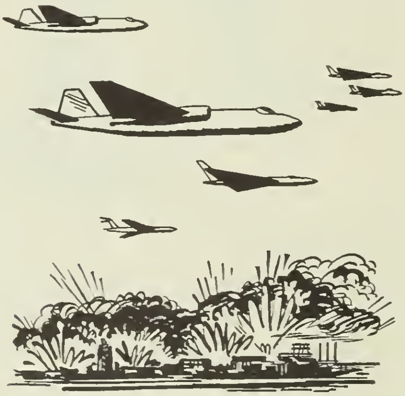
Great Britain realizes, however, that she can no longer hope to achieve these objectives on her own. She therefore accepts the idea that the Royal Air Force, in particular Bomber Command with its current thermonuclear capacity, must function in cooperation with other air forces as a component of over-all Allied air power.

On April 4, 1957 the United Kingdom Government issued a White Paper[6] on defense, involving what was described as "the biggest change in military policy ever made in normal times." Over a period of five years, the Royal Air Force is to be completely reshaped. There will be a reduction in numbers, a change to a completely professional force, a greater emphasis on guided missiles for defense and offense, and a building up of highly mobile home-based striking forces for rapid reinforcement of overseas garrisons.

Governmental control of the Royal Air Force is carried out through the Air Ministry, a department similar in many respects to the Department of the Air Force in the United States. The Air Ministry has charge of manning, administration, and organization, and contains within itself the Air Staff, headed by the Chief of Air Staff, which is responsible for strategic planning.

The Royal Air Force has since its formation in 1918 been organized functionally at home, and geographically overseas. There are four operational commands in the United Kingdom—Bomber, Fighter, Coastal, and Transport. Behind these stand the support commands—Flying Training Command, Technical Training Command, Maintenance Command (the British equivalent of our Air Materiel Command), and Home Command (the British equivalent of our Continental Air Command).

Outside of Great Britain the Royal Air Force adapts itself to demands, with theater air commanders being accountable for all types of operations carried out in their areas of responsibility. The Middle East Air Force, with headquarters at Cyprus, has a sphere of interest stretching from the Mediterranean down to South Africa, and from Malta east to the Indian Ocean. Some overlapping occurs in the Mediterranean with the various NATO commands in that area, notably at Malta, which is both a British bastion and an important NATO base. In the Far East the Royal Air Force's sphere of interest covers the area from Ceylon through Southeast Asia to Hong Kong on the coast of China. British Far East Air Force Headquarters is situated at Singapore. Apart from these major overseas commands, Britain also maintains the 2d Tactical Air Force in Germany as a NATO commitment, and the RAF Light Bomber Force, which is assigned to NATO but based in the United Kingdom. Under the new defense policy, Britain's 2d Tactical Air Force will lose about half of its present number of aircraft by the end of March 1958 but will make up for the loss by turning to atomic weapons. A similar reduction will take place in the NATO-assigned Light Bomber Force.



Bomber Command

The RAF War Manual states simply: "Since the basic strategy of air power must be offensive, the bomber will be its primary agent." It has been argued that because the United Kingdom is a member of NATO, the RAF should concentrate its limited resources on fighters or guided missiles for the defense both of Britain and those NATO nations which lack the productive capacity to make their own fighters and guided missiles. British military leaders, however, have never had any illusions about the possibility of a 100 percent-effective air defense system. They have always held to the belief that attack is the best means of defense.

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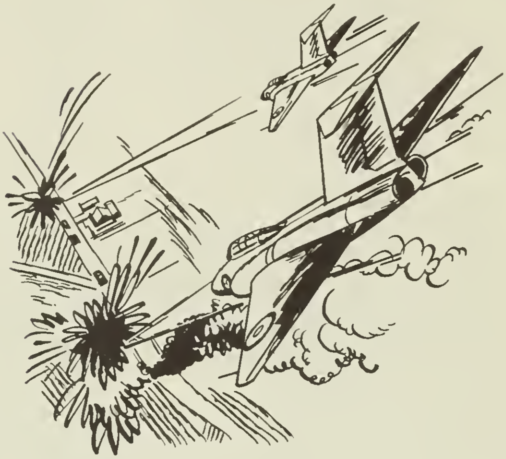
[6] Official report on governmental policy.

The United Kingdom, with its high population density and concentrated productive capacity, is an ideal target for thermonuclear warfare. A relatively small number of these weapons could well be quickly fatal. The British therefore look upon a strong nuclear bomber force as an absolutely essential deterrent. They also see it as an equally essential means of striking back at an aggressor should war come. Hot war aside, they regard that force, furthermore, as an indispensable instrument of national policy, one that will reinforce and build respect for British views in the councils of the world.

RAF Bomber Command has in recent years been going through a period of transition from a piston engine force to an all-jet force complete with modern all-weather bombing equipment. Although with its present equipment the Command does not have a truly long-range strategic capability, it needs one less than the United States does because it lies closer to a number of potential enemy targets. Current British policy calls for the retention of Bomber Command with its thermonuclear capacity, but research will henceforth concentrate on intermediate range ballistic missiles.

Although Great Britain took an early lead in the jet transport field, progress in military aviation has until recently reflected the financial restrictions imposed by a tight national economy. It has taken a dozen years, for example, to bring Bomber Command's equipment up to date. And, for a number of reasons, fighter development has also lagged until recently. The British aero-engine industry, however, has steadily maintained its lead internationally with a succession of new, improved power plants. To the well-tried engines in production have been added more advanced small, medium, and large turbines, which offer high power-to-weight ratios, great development potential, and improved economy.



FIGHTER COMMAND

Fighter Command has been an all-jet force since 1948. Until recently its strength consisted largely of day fighters whose basic designs derived from specifications laid down by the Air Ministry early in the Second World War. With the advent of the Hawker Hunter, however, Fighter Command began to move into a new era. The Hunter, after a somewhat troubled start, has now settled into squadron service. Complementing it is the Gloster Javelin, all-weather fighter, a twin-jet craft which is appearing in increasing numbers. But the pace of progress has already left these two subsonic interceptors behind. Replacing them will be the English Electric P. 1, a promising supersonic design, which should become operational some time in 1958. The P. 1 seems destined to be the Royal Air Force's last manned fighter. The general future in air defense includes, of course, the missile, which in Britain comes under RAF control, and research efforts are concentrating heavily on the development of this kind of weapon.

Fighter Command's assigned task is to provide for the air defense of the United Kingdom and its coastal waters. The aim is to achieve so high a degree of efficiency that no enemy will be able to penetrate Britain's air defenses without suffering heavy losses. A parallel aim is to achieve that efficiency with a minimum outlay. The British feel that it would be a mistake to devote too high a percentage of their limited resources to an effort that may never give them complete protection. To do so would be to run the risk of fatally weakening the air-atomic offensive power upon which they chiefly rely for survival.

U. S. Air-Force Photo

British Gloster "Meteor" aircraft in vertical flight.

U. S. Air Force Photo

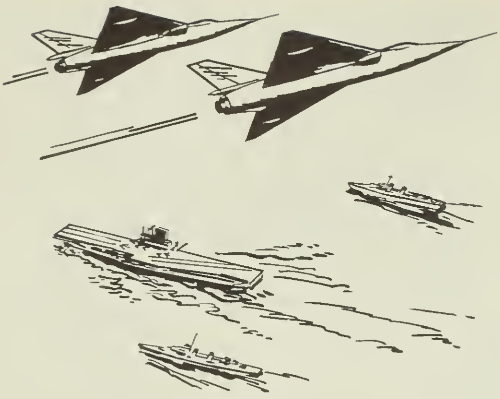
British Fairey Delta 2, a supersonic experimental research jet aircraft.

Courtesy British Information Service

The Saunders Roe S–R 53, Great Britain's first manned plane to use a rocket as its main power plant.

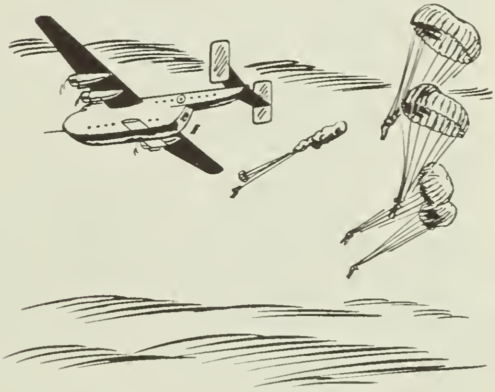
U. S. Air Force Photo

British Hawker "Hunter" jet fighter. Note the missile attached to the wings.



COASTAL COMMAND

The principal duty of Coastal Command is to work in partnership with the Royal Navy to keep the sea lanes to Britain open. The United Kingdom must import to live, and Coastal Command's task is to help see to it that nothing stops the flow of imports. This task calls for aircraft which can fly far, maneuver well, and carry a varied load of weapons. Coastal Command's great antagonist is of course the submarine, and the race to devise ways and means of countering its developing threat is an endless one.



TRANSPORT COMMAND

The function of Transport Command is the strategic movement of men and material to overseas theaters and the provision of airlift to the Army for airborne operations, troop movements, and air supply. Transport Command is scheduled for a substantial enlargement under the new defense policy. In an emergency it would be able to supplement its strength by drawing on the resources of British civil aviation. The entry into service of such modern transports as the turboprop Viscount and Britannia, and the turbojet Comet II should enable the Command to provide strategic mobility not only to the RAF, but also to the Army. Such mobility is extremely important in dealing with both cold and hot war situations.

The British realize that the RAF cannot protect them by adopting a purely defensive strategy. At the same time they also realize that the island of Great Britain, which has been likened to an enormous aircraft carrier firmly anchored off the coast of Europe, is not an ideal place from which to conduct a modern strategic air offensive. It is too small and too crowded. The lands of the Commonwealth, by contrast, offer more than enough room for dispersion. Furthermore, they are so well scattered over the globe as to make it possible to menace the enemy from all points of the compass and force him to spread his defenses. It is true of course that the mounting of an air offensive from here, there, and everywhere around the world presupposes a chain of well-prepared airdromes linked by adequate transport. Some of the bases already exist; others are under development; and British air transport, as noted above, is on the upswing. Strategic offensives aside, Commonwealth air bases, particularly those in the troubled region from Malta east to Singapore, can be of great use in the handling of local outbreaks.

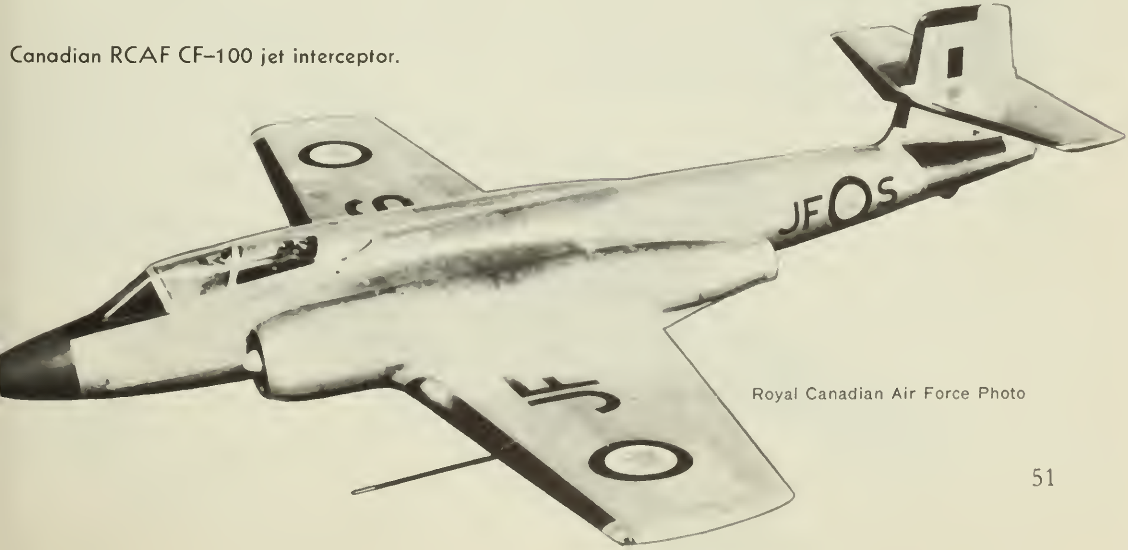
Whatever the requirements may be, and wherever they may arise, Britain's air power will have to meet them. The British have made up their minds that only two kinds of war are now possible: the all-out nuclear struggle, and the limited brushfire operation. And they are reshaping the Royal Air Force so that if the need should come it can undertake either.

After a postwar lull, Canada began to reorganize and expand her air force in 1950. Although the immediate reason was the outbreak of war in Korea, the change was also an indication of Canadian belief in air power as the best insurance against a general war. That belief has not wavered since. The Royal Canadian Air Force today has a threefold mission: (1) to defend Canada against air attack; (2) to furnish forces in support of Canada's commitment to NATO and any other collective security organization which she may join; and (3) to provide in peacetime a strong nuclear force that can be greatly expanded in the event of a total war.

The RCAF is functionally organized into four home operational commands—Tactical, Transport, Air Defense, and Maritime. There is also an air division of 12 fighter squadrons based in Europe with the NATO forces. Supporting all these elements are the Air Material Command and the Training Command. Canada's limited military budget cannot support both offensive and defensive air forces of any effective size. The RCAF has therefore concentrated on air defense and left the development of offensive striking power to the USAF. This is understandable, for Canada in spite of its prosperity and phenomenal growth is still a middle-sized power. Its territories are vast, but its population is small. Its future is unlimited, but its present capacity is not.

The RCAF's defense role is a double one. It protects Canada and also stands guard over the northern approaches to the entire continent. Canadian air defense plans are closely interwoven with those of the United States, and an RCAF air marshal serves as deputy to a USAF supreme commander in the combined North American Air Defense Command (NORAD). NORAD relies for radar detection and warning on the DEW Line (Distant Early Warning Line) in the Far North, the Mid-Canada Line along the 55th parallel, the Pinetree Line in southern Canada and northern sections of the United States, and a diverse array of picket ships, Texas Towers, airships, and radar aircraft in the offshore areas of the continent. The Canadian contribution to this complex combined warning system is heavy. No less impressive is the RCAF contribution to NORAD's fighter defense forces. The CF–100 is a first-class interceptor, and coming along as its successor is the new CF–105 (ARROW), a supersonic all-weather fighter. Both these aircraft are Canadian-designed

Canadian RCAF CF–100 jet interceptor.



Royal Canadian Air Force Photo

and Canadian-made. Plans are also being made to integrate guided missiles into Canada's defenses.

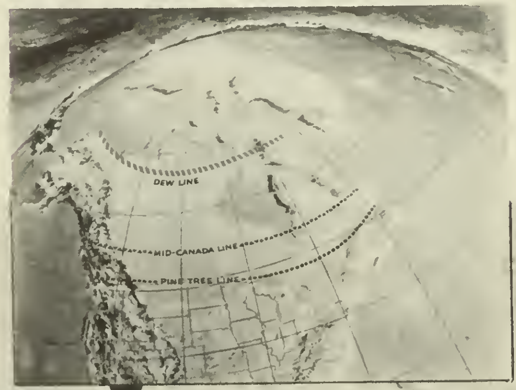
The RCAF Transport Command has the function of moving men and materials as required to support air operations. In addition it is responsible for providing assistance to the Army for air transported operations and air drop of men and supplies. Although small in size, the Command can meet all RCAF requirements. One squadron flew beside the USAF carrying troops and supplies to and from the operational theater during the Korean War. Another squadron operated during 1957 in Egypt with the United Nations Emergency Force.

All technical ground training and aircrew training within the RCAF is carried out by Training Command. The Command also has had the task of training aircrew members for NATO. This ambitious program, which saw Canadians teaching airmen from Norway, France, the Netherlands, Belgium, Italy, Greece, and Turkey, is now nearing completion. But before it ends, Training Command will have carried out the added task of training aircrew members from the latest country to join NATO, West Germany.

As an able self-supporting member of NATO, Canada has provided that organization with an air division of 12 fighter squadrons, complete with support units, headquarters, and a radar complement. The division, flying Canadian-built jet aircraft, is based in Europe as part of NATO's integrated fighter force. Under a mutual defense assistance agreement Canada has supplied many front-line aircraft to Turkey and Greece. RCAF advisory groups have been established in these two countries to assist with the conversion and technical training programs.

The RCAF has a small reserve force which was reorganized in 1956. It consists primarily of headquarters units, radar control squadrons, and jet fighter squadrons. These reserve forces are designed to support Air Defense Command in time of emergency.

U. S. Air Force Photo



Map showing location of DEW Line, the Mid-Canada Line, and the Pine Tree Line. Below is an aerial view of a typical DEW Line radar detection station.

U. S. Air Force Photo

Australia

The Royal Australian Air Force, with headquarters at Penrith, has three main tasks. They are to provide and maintain a task force, provide fighter defense at home, and protect the sea lanes. Although Australia still uses some reciprocating engine aircraft obtained from the United States and Britain, it now relies mostly on jet types produced in Australian factories. This country is continuing to provide a good share of the military air power needed for the protection of its part of the free world against aggression.

West Germany[7]

German military traditions and political considerations, as well as the rapid pace of technological development, will in all likelihood influence the future development of the new German Air Force as much as present NATO and United States plans for the role it is to play in the Western alliance. Though much has been written on the subject of West German armament in recent years, reliable and detailed information is rather limited. German military leaders have said little, presumably not only for reasons of security but also because rearmament is a hot political issue in Western Germany.

The North Korean attack in June 1950 provided the impetus for Western plans to reverse the previous policy of keeping West Germany indefinitely demilitarized. Western political and military leaders, particularly in the United States, interpreted the invasion as a clear warning that the forces of Communism might soon launch an attack against Western Europe through West Germany. Secretary of State Dean G. Acheson therefore proposed the creation of West German armed forces at a meeting of the foreign ministers of Britain, France, and the United States, the three Western occupation powers, in September 1950. More than five years were to elapse before the first Germans donned uniforms. The major reason for the delay was difficulty in reconciling conflicting national viewpoints on the need for and nature of West German rearmament. Not until the Paris Agreements of October 1954 did the powers settle on a final formula, and another fifteen months passed before the first German units went into training.

Under the terms of the allied agreements providing for the armament of West Germany, the new air force is to be strictly a tactical force. It is to include no strategic bombers, and its contemplated combat strength is to be about 1,000 fighters and fighter-bombers. Slated to become a major component of NATO's tactical air force in central Europe, the German Air Force appears designed primarily for counter-air, ground support, reconnaissance, airlift, and possibly interdiction operations.

The new Luftwaffe is likely to be only a pale shadow of its predecessor, at least in terms of numbers. With a first line combat force of 3,750 planes and one and a half million men, the old Luftwaffe was in 1939 an autonomous branch of the armed forces, coequal with the other services. Almost all military aviation and air defense units were under its control. The new air force appears destined to be only a minor component of the German defense establishment. It will have no more than 80,000 men (about one-fifth the manpower of the ground forces), only a part of the totality of military aviation, and no control over ground-based air defense. In addition to the 1,300 planes of the German Air Force, there will be about as many aircraft—spotters, liaison planes, helicopters, and the like—under the control of the other services, particularly the Army.

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[7] Adapted from Dr. Lewis J. Edinger, "Concept of the West German Air Force", *Air University Quarterly Review,* VIII (Summer 1956), pp. 46–58.

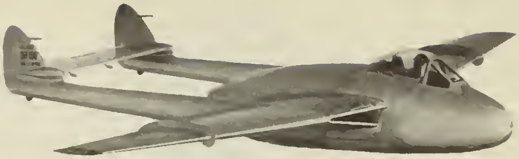
The latest available data on the contemplated organization of the German Air Force supports the impression that, contrary to earlier plans, its anti-air mission is being de-emphasized. Fewer fighter-interceptor wings and more tactical reconnaissance and fighter-bomber wings are now being planned for. The Luftwaffe's ground support mission of the Air Force in particular appears to be assuming primary importance in the minds of Defense Ministry planners, most of whom were command and staff officers of the wartime army.

One of West Germany's big problems in building its new air force is getting qualified volunteers. Most of the early applications came from Luftwaffe veterans too old for extended duty or otherwise ineligible. Some of the most highly qualified air veterans had established themselves in civilian occupations and were unwilling to abandon these; others were ready to serve but could not because of their association with the Nazi regime. Probably no more than a few hundred veterans can be used in the new air force, and those will serve as instructors and in command and staff positions. For most of its personnel the Luftwaffe will have to rely upon youngsters who did not see service in World War II and are largely indifferent to the traditions and experiences of their seniors.

Under the allied agreements providing for the arming of West Germany, the deployment of German air units, as well as ground and sea formations, is to be determined by the NATO Supreme Allied Commander. Present indications are that in peacetime German authorities will retain considerable direct control of the air force, while SHAPE (Supreme Headquarters, Allied Powers in Europe) and its subordinate commands will concentrate on tactical and strategic planning. In case of war the NATO commanders will resume direct command.

The strategic planning that prompted the arming of West Germany envisioned the combat mission of the German Air Force to be the provision of tactical air support to NATO forces in central Europe, in close cooperation with other elements of the alliance such as the United States Strategic Air Command. While SAC would strike at the enemy interior, German and other allied tactical air forces in Europe would erect an air barrier against the advance of enemy ground units and participate in mopping-up operations. Presumably this would be the plan of operation both if West Germany were attacked directly or if the initial attack were aimed at some other member of NATO. German Air Force training and development in peacetime, as well as deployment in wartime, would be governed by these over-all NATO plans.

German military traditions, security considerations, and political problems may well force modification of certain concepts regarding the new German Air Force now held by NATO and U. S. military planners. What appears to be specifically German needs are likely to bulk larger in the minds of the leaders of the Federal Republic than allied plans. Tact, flexibility, and willingness to compromise will be required both in the councils of NATO and the German military establishment if the new German Air Force is to make a real contribution to the defense of the West.

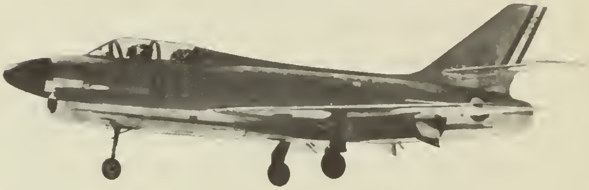


French "Mistral".

U. S. Air Force Photo

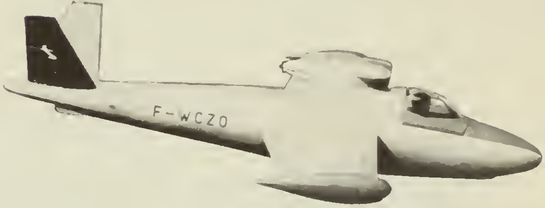
France

Although France has been bothered by an inadequate budget, she has recently produced several aircraft of modern and competitive design. France's aim generally is to replace foreign types with local designs and to introduce new advanced aircraft. France, being a continental nation with several land frontiers, is concerned for the safety of expensive and vulnerable airfields. It is perhaps with airfield costs and vulnerability in mind that French aeronautical engineers are experimenting with aircraft requiring only a platform for takeoffs and landings. Though the factories used by the Germans during their 1940–1944 occupation of France have been modernized, the French still find it necessary to purchase aircraft from the United States and Britain and to keep using a considerable number of British and American planes that saw service with the *Armée de l'Air* before V–E Day. But the French aircraft industry has moved back into the first rank and can be expected to turn out supersonic interceptors whose quality and quantity will add much to Western defensive strength.



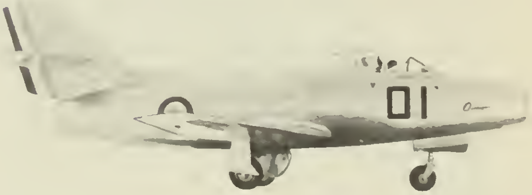
The French Marcel Dassault "Mystere" IV N.

U. S. Air Force Photo



French Fouga CM8–R "Midjet".

U. S. Air Force Photo

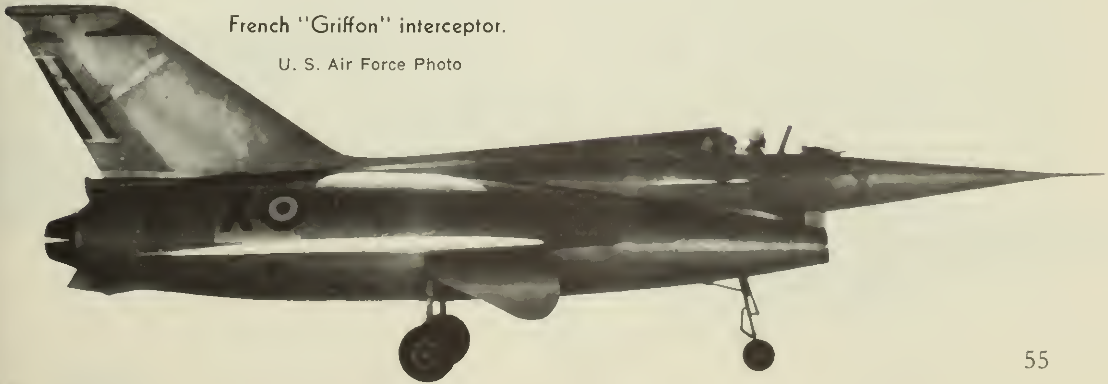


French MD–450 "Ouragan".

U. S. Air Force Photo

French "Griffon" interceptor.

U. S. Air Force Photo

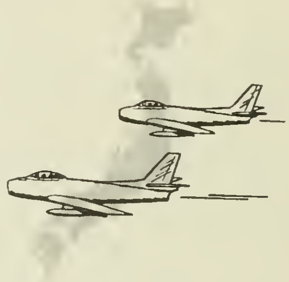


Latin America

Since the signing of the Rio Treaty of 1947 and the establishment of the Organization of American States (OAS) in 1948, Latin America has become a full hemispheric defense partner. Several Latin American countries have moved out into the world and made great strides in developing and training their armed forces. Military missions from the United States have been at work assisting in this program in almost every one of the republics. Aircraft, weapons, and equipment have been purchased by these countries as a part of their participation.

The governments south of the border are currently becoming jet-minded and are buying modern United States aircraft. A number of Latin American countries have already begun to build their air forces around the jet fighter, while others are ready to invest in this endeavor. Militarily this is a healthy trend because it means improved air power for the Western Hemisphere. It also indicates a sincere desire on the part of our Southern neighbors to pay their own way for defense.

To obtain advanced United States planes, these nations work through the USAF under an arrangement known as Reimbursable Military Assistance, which is a part of the over-all Mutual Defense Assistance Program. Reimbursable Military Assistance is not an affair of charity, but rather a means by which proud people pay for what they get. The first sale of United States jets to a South American government under RMA took place in 1955, when Colombia bought six T–33 jet trainers. At a small but impressive ceremony at the Pentagon, Colombia presented the United States Government with a check for $1,162,000 as payment for the aircraft and for their support for one year. Since that time other Latin American countries have bought many more. Venezuela, for example, paid some eight million dollars for 22 Sabrejets, and the Dominican Republic took another 25 of them at a cost of nine million dollars.



Japan

The buildup of the new Japanese air defense force has been plagued by popular memories of what happened at Hiroshima and Nagasaki. Many Japanese fear that a revival of the country's air power will only invite new nuclear destruction. But, in spite of this concern, the Japanese Air Defense Force came into being in July 1954, and since then the Japanese Government has taken steps to provide for the domestic assembly and manufacture of modern jet trainers and fighters.

Japanese Fuji TIF2 jet trainer.

Sweden

There are some nations that prefer to go it alone. Sweden, for example, a nation quite vulnerable to attack, has built an impressive small air force—underground. The Swedish Air Force is based underground, and the jets it uses are made in underground plants that have been cut out of rock.

The Swedish Air Force has been independent since 1926. The kingdom has one of the world's most colorful air academies, where air officers received their education in an atmosphere reminiscent of the American service schools. When they have finished their academic training, young Swedish air officers take up posts in an air force that remains alertly abreast of the latest developments. The Swedes feel that to lag militarily is to invite ruin. For that reason they embarked in 1955 on a ten-year defense modernization program which charted a leading role for guided missiles. Swedish missile launching sites parallel the Soviet guided missile bases along the Baltic coast. Sweden stands poised and defiant, ready to meet aggression if it comes.

U. S. Air Force Photo

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Swedish Air Force Dragon fighter. It features the world's most extreme delta wing.

Swedish Air Force J–35 fighter.

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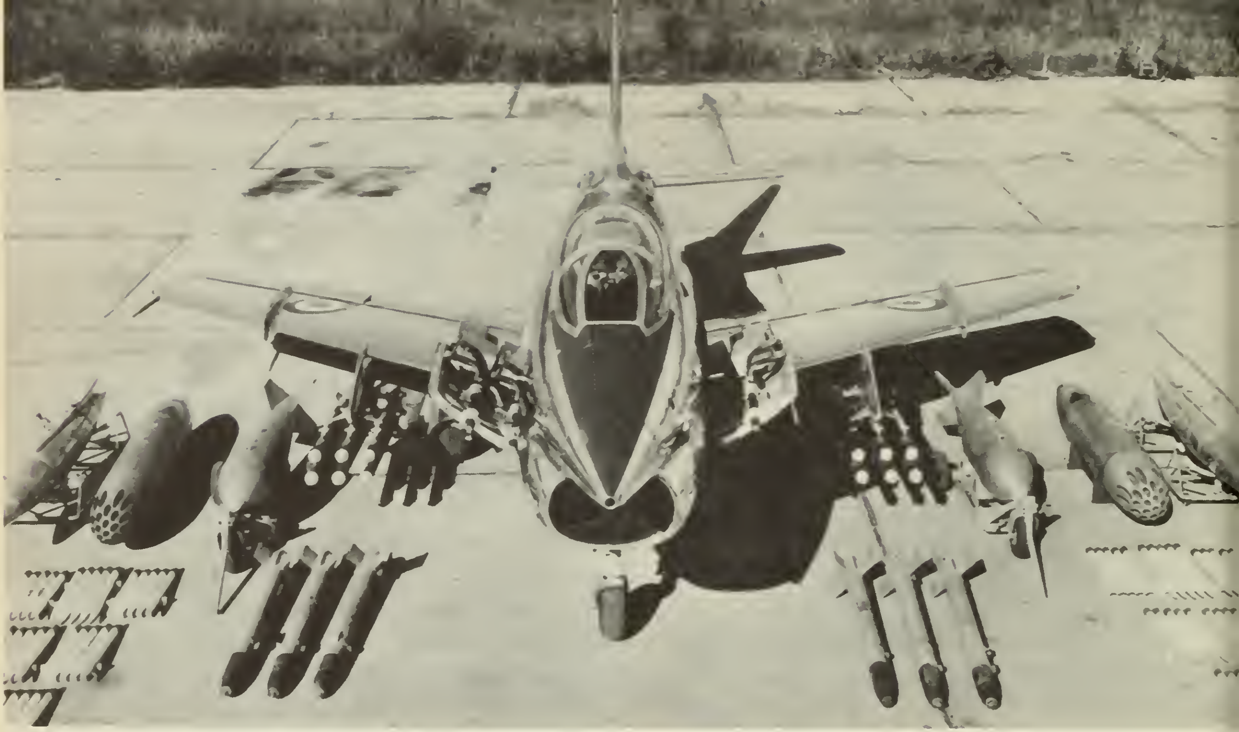
U. S. Air Force Photo



Courtesy of AVIATION WEEK

Italian Air Force Fiat G.91 fighter with armament.

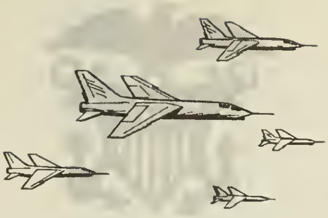
Italy

Italy has made significant strides in military aviation since its defeat in World War II.

The Italian aircraft industry, virtually destroyed during the war, has regained the capacity to produce planes of high quality but has to depend mainly on foreign orders for its survival. Through a special licensing agreement, the Fiat company is also building North American F–86Ks for NATO forces.

Owing to lack of funds, the Italian Air Force has had to conduct its postwar life largely with handouts of surplus USAF aircraft. Traditionally an independent military service, it has made a noteworthy comeback in recent years and is now an all-jet operational arm. Its present combat planes are primarily of the sweptwing type, mainly F–86Ks produced by Fiat, North American Sabre 4s built by Canadair, and Republic F–84Fs and RF–84Fs.

Air Force operations are limited to three missions: air defense, ground support, and naval support. Foreign military observers in Italy have high praise for its air force. They speak of the significantly high percentage of airplanes that are available for immediate operational service, low accident rates, and noteworthy pilot prowess in gunnery. Though small, the Italian Air Force plays an important part in the defense of Western Europe. The strategically located Italian peninsula—extending for 700 miles from the Alps almost to Africa—forms a vital link in the NATO defense chain stretching around the Soviet-controlled states of Eastern Europe. Military aircraft based in Italy are thus in a unique position to ward off possible attacks coming from the Balkans or the Danube Basin; to react quickly to crises in North Africa and the Near East; and to establish air control over vital sea lanes running through the Mediterranean.



The United States of America

Naval Aviation

Naval aviation is a major component of modern sea power. It is also a significant part of the totality of military air power. The primary mission of American naval aviation is to gain and keep command of the air in support of fleet operations. In carrying out this mission our fleet air arm does not function as an autonomous or separate fighting organization. This fact is important for an understanding of the term *naval aviation.* Whatever its strategic or tactical possibilities may be, the naval air force works primarily as an adjunct of the fleet, serving fleet purposes. The naval air force, as a tactical weapon, is part of the fleet—just as are the submarine, destroyer, cruiser, and amphibious forces. Broadly speaking, there is no separate aviation corps within the Navy, either administratively or operationally. Naval aviators are subject to assignment wherever their experience and training are likely to help them do the job better than other officers.

ORGANIZATION. The following brief discussion of the organization of the naval air arm seeks to provide a basis for a better understanding of the way in which naval aviation contributes to American military air power.

The Deputy Chief of Naval Operations for Air advises the Chief of Naval Operations about aviation matters and serves as the Navy's principal aviation planning and policy officer. The actual deployment of naval air units is in the hands of the Deputy Chief of Naval Operation for Fleet Operations, who usually consults, however, with the Deputy Chief of Naval Operations for Air.

The DCNO (Air) has a host of responsibilities. He plans and controls the program for all naval air bases, aircraft, facilities, and technical equipment. He establishes aviation personnel requirements for both the regular Navy and the Naval Air Reserve, and estimates replacement needs. He is concerned with technical and flight training. Through the Bureau of Naval Personnel, he controls the assignment of all naval aviators. He also draws up plans for the number of squadrons of each type, the complement of aircraft squadrons, and the military characteristics of naval aircraft. Finally, he controls and coordinates the guided missile program for the entire Navy and acts as a member of the Ship Characteristics Board, which determines what and how many new ships the Navy will have.

The range of the duties of the Deputy Chief of Naval Operations for Air may appear to leave little for the Bureau of Aeronautics[8] to do. But it has responsibilities enough. It implements plans for the development and procurement of new aircraft; provides for the maintenance and repair of bases, aircraft, and aircraft equipment; and handles the procurement of aviation fuel and lubricants.

Probably the most important function of the Bureau of Aeronautics is that of getting appropriations from Congress to support naval aviation. Each year the Navy asks Congress for funds to cover the maintenance and operation of naval air stations used in training and logistic support. Although training at sea is emphasized in both peace and war, it seems to be less than desired. This is because the time and effort required to train aboard ship are not proportionate to the benefits received. In fact, if all training had to take place at sea, squadrons could not

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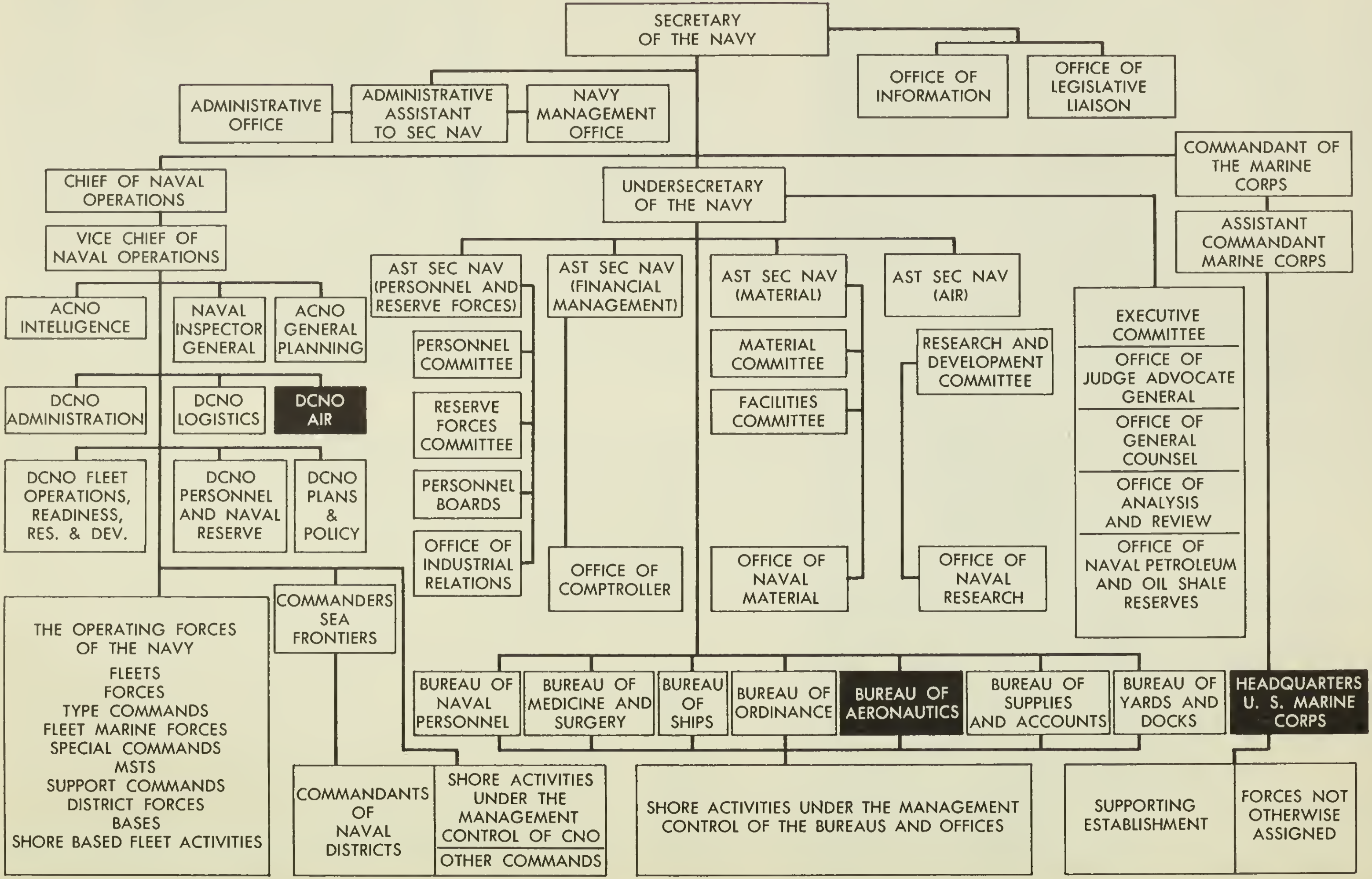
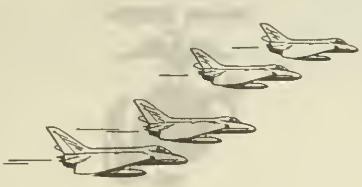
[8] The Bureau of Aeronautics is a Navy Bureau, created in 1921, charged with matters pertaining to naval aeronautics as prescribed by the Secretary of the Navy.

DEPARTMENT OF THE NAVY


SECRETARY OF THE NAVY
OFFICE OF INFORMATION
OFFICE OF LEGISLATIVE LIAISON
ADMINISTRATIVE OFFICE
ADMINISTRATIVE ASSISTANT TO SEC NAV
NAVY MANAGEMENT OFFICE
COMMANDANT OF THE MARINE CORPS
ASSISTANT COMMANDANT MARINE CORPS
CHIEF OF NAVAL OPERATIONS
VICE CHIEF OF NAVAL OPERATIONS
UNDERSECRETARY OF THE NAVY
ACNO INTELLIGENCE
NAVAL INSPECTOR GENERAL
ACNO GENERAL PLANNING
DCNO ADMINISTRATION
DCNO LOGISTICS
DCNO AIR
DCNO FLEET OPERATIONS, READINESS, RES. & DEV.
DCNO PERSONNEL AND NAVAL RESERVE
DCNO PLANS & POLICY
AST SEC NAV (PERSONNEL AND RESERVE FORCES)
PERSONNEL COMMITTEE
RESERVE FORCES COMMITTEE
PERSONNEL BOARDS
OFFICE OF INDUSTRIAL RELATIONS
AST SEC NAV (FINANCIAL MANAGEMENT)
OFFICE OF COMPTROLLER
AST SEC NAV (MATERIAL)
MATERIAL COMMITTEE
FACILITIES COMMITTEE
OFFICE OF NAVAL MATERIAL
AST SEC NAV (AIR)
RESEARCH AND DEVELOPMENT COMMITTEE
OFFICE OF NAVAL RESEARCH
EXECUTIVE COMMITTEE
OFFICE OF JUDGE ADVOCATE GENERAL
OFFICE OF GENERAL COUNSEL
OFFICE OF ANALYSIS AND REVIEW
OFFICE OF NAVAL PETROLEUM AND OIL SHALE RESERVES
THE OPERATING FORCES OF THE NAVY
FLEETS
FORCES
TYPE COMMANDS
FLEET MARINE FORCES
SPECIAL COMMANDS
MSTS
SUPPORT COMMANDS
DISTRICT FORCES
BASES
SHORE BASED FLEET ACTIVITIES
COMMANDERS SEA FRONTIERS
COMMANDANTS OF NAVAL DISTRICTS
SHORE ACTIVITIES UNDER THE MANAGEMENT CONTROL OF CNO
OTHER COMMANDS
BUREAU OF NAVAL PERSONNEL
BUREAU OF MEDICINE AND SURGERY
BUREAU OF SHIPS
BUREAU OF ORDINANCE
BUREAU OF AERONAUTICS
BUREAU OF SUPPLIES AND ACCOUNTS
BUREAU OF YARDS AND DOCKS
HEADQUARTERS U. S. MARINE CORPS
SHORE ACTIVITIES UNDER THE MANAGEMENT CONTROL OF THE BUREAUS AND OFFICES
SUPPORTING ESTABLISHMENT
FORCES NOT OTHERWISE ASSIGNED

meet Navy standards of efficiency and safety. Naval aviators first learn to operate from land bases; only later, during periods aboard ship, do they go on to the task of coordinating their tactics with those of the fleet.

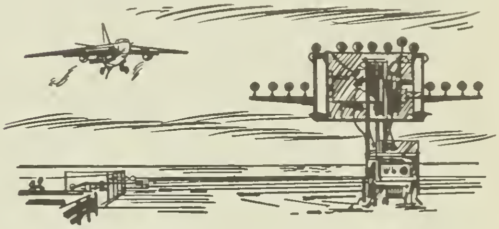


Marine Aviation. The United States Marine Corps is a separate military organization within the Department of the Navy. The primary mission of the Marine Corps is to provide Fleet Marine Forces, which include air components, for seizing and defending advanced naval bases and conducting operations essential to a naval campaign. The Corps also develops, in coordination with the Army, the Navy, and the Air Force, the tactics, techniques, and equipment used by landing forces in amphibious actions. Fleet Marine Forces consist of Marine divisions, Marine aircraft wings, and such other supporting elements and bases as are required. The operational control of the Fleet Marine Forces normally belongs to the two major fleet commanders (Atlantic and Pacific).

The primary function of Marine aviation is to provide air support to the Fleet Marine Forces in the execution of amphibious operations. It does this with ship-based or shore-based aircraft, or both. Marine air training reflects the stress on support work, and the results of this specialization can be seen in the splendid *esprit de corps* of the Corps' Air-Ground Team.

A secondary mission of Marine aviation is to furnish replacement squadrons to the carriers of the fleet. During the early phases of an amphibious operation against a distant objective, the Marines usually provide ship-based air support to supplement the Navy air effort. As soon as existing or prepared airfields become available the Marines carry on from land bases. These replacement squadrons may be assigned any task normally given to similar Navy squadrons. For such reasons, all Marine combat air squadrons are assigned carrier aircraft types, and Marine pilots using these aircraft must be able to operate from carriers. With such capabilities, Marine aviation constitutes an extremely valuable emergency reserve for carrier striking forces.

Marine aviation depends completely on the Navy for aeronautical logistic support and flight training. The Marines provide the Navy with some administrative personnel for logistic support, and also furnish flight instructors to the Naval Air Training Command.



Fleet Air Organization. All organized combat squadrons of the Navy and of the Marine Corps are assigned to duty in the two major fleets, Atlantic or Pacific. The ships and aircraft squadrons of the two fleets are formed into task forces to carry out operational missions. In the category of task forces are the Naval Forces, Eastern Atlantic and Mediterranean, and the Naval Forces, Far East, which operate under their respective theater commanders.[9]

A fleet air commander operates immediately under the fleet's commander-in-chief.

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[9] A theater commander is the officer in command of all military forces—air, land, sea—within a theater of operations. A theater of operations is a geographical region with the airspace above it, designated by competent authority to be under a single over-all commander. A theater commander belongs to a particular service, but in the exercise of his responsibilities he stands above service considerations.

He has administrative command over the aircraft squadrons of the fleet and is responsible for their tactical training and readiness. He also exercises somewhat limited operational functions connected with training, the movement of squadrons and air groups, and the ferrying of aircraft overseas. When aircraft are embarked on ships, operational control over them passes to the ship, or to the commander of the task force to which the ship is assigned.

Fleet air commanders and their subordinates have fixed headquarters ashore. But fleet air wing commanders do not. They function at sea, and their commands consist of three or more squadrons of patrol planes, plus whatever seaplane tenders are assigned. Though the commanders of fleet air wings have full administrative and logistic responsibility over their forces, their primary duties are operational.

Each major fleet also has a number of utility squadrons formed into wings. These wings are charged with local aerial photography and the air transport of mail and personnel on nonscheduled flights within limited areas, but their main functions are to tow targets and to operate drone target aircraft.

U. S. Navy Photo

▲
U. S. Navy F9F–6's Cougars.

U. S. Navy Photo

▲
U. S. Navy carrier-based XF3H–1 "Demon" fighter.

U. S. Navy Photo

▲
U. S. Navy F2H–1 Banshee supersonic fighter.

U. S. Navy Photo

▲
U. S. Navy A4D–4 Skyhawk.

U. S. Navy Photo

◀ Formation of U. S. Navy Skyrays.

U. S. Navy Photo

U. S. Navy aircraft carrier Antietam (CVA–36) off the Virginia Capes.

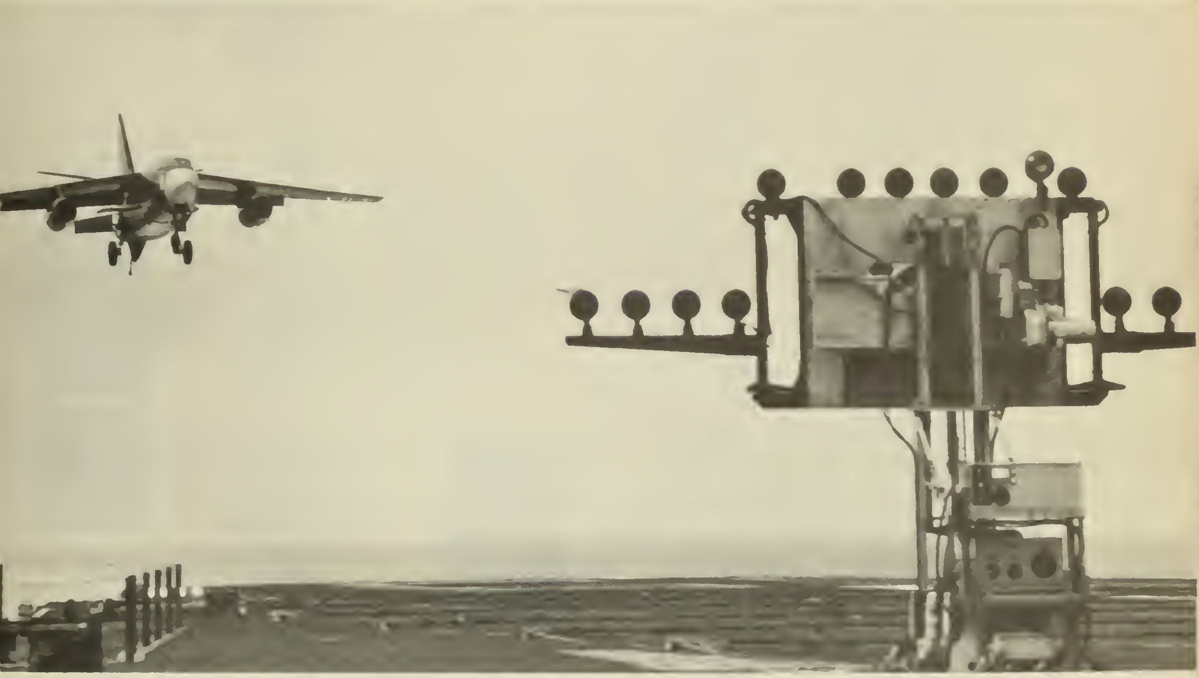
THE AIRCRAFT CARRIER. Several types of aircraft carriers are now in service. Carriers of the 60,000-ton Forrestal class, the 45,000-ton Midway class, and the converted 35,000-ton Essex class are all designated as attack carriers (CVA's). Unconverted 35,000-ton Essex class carriers operate in antisubmarine warfare and carry the designation CVS. (The light 20,000-ton escort carriers [CVE's] formerly used against submarines now function routinely as aircraft transports.) In addition to the heavy combat types a new light carrier (CVAN) is being developed to support helicopters during the vertical envelopment phase of amphibious landings.

Carriers require aircraft of special design, owing to space limitations aboard ship and the forces encountered in normal deck operations. As a result a carrier aircraft must have folding wings to save room and reinforced landing gear and fuselage to absorb the shock of catapulted launchings and arrested landings.

Carrier operations are somewhat complicated because of the restricted size of the landing, parking, and takeoff areas. But the combination of skilled pilots and such shipboard specialists as landing signal officers, plane directors, plane parking crews, and operators of arresting gear and barriers makes possible smooth and efficient operations.

The carrier is in reality a mobile air base, and like any air base it needs centralized control over its operations. Each carrier has a combat information center which maintains a plot of all aircraft within radar range and instantly reports the presence of hostiles to the commanding officer within the area. As at any base, navigational aids are available aboard a carrier to help pilots find their way home; and repair facilities are also at hand for aircraft damaged in flight.

Apart from carrying out its primary mission of gaining and keeping command of the air in support of fleet operations, the naval air arm can also assist the USAF in certain other operations by providing advanced intelligence, photo reconnaissance, and early warning radar services; by giving fighter cover; and by destroying enemy fighter and missile bases.



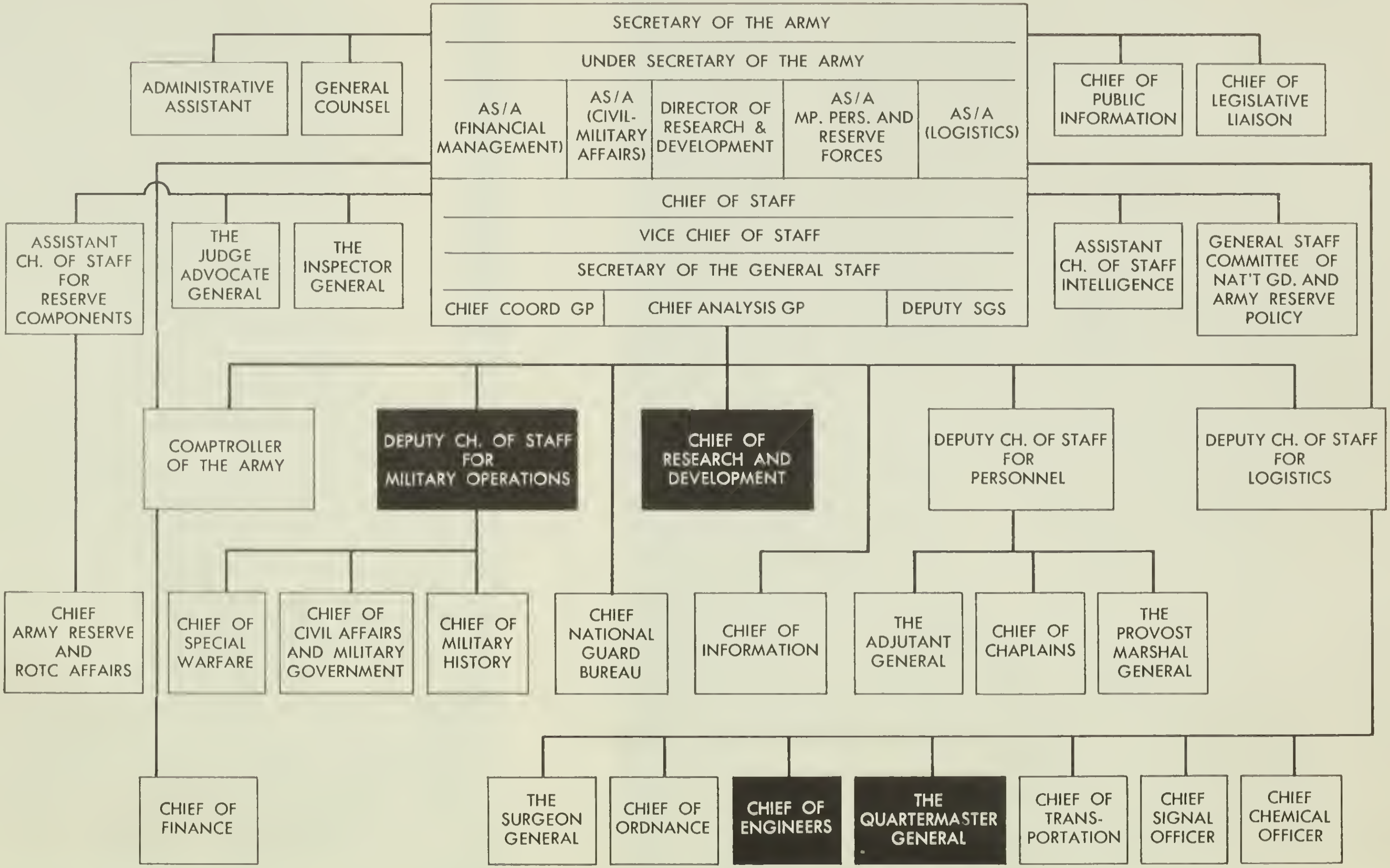
U. S. Navy Photo

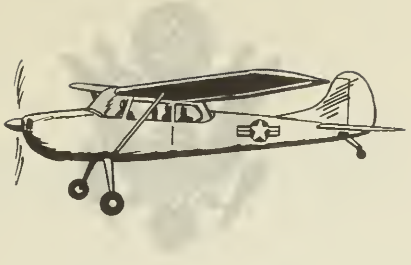
▲ U. S. Navy aircraft carrier Antietam (CVA–36) off the Virginia Capes. Carrier landing by mirror.

U. S. Navy Photo

A Navy F9F–5 being prepared for catapulting off carrier flight deck.

DEPARTMENT OF THE ARMY


SECRETARY OF THE ARMY
UNDER SECRETARY OF THE ARMY
AS/A (FINANCIAL MANAGEMENT)
AS/A (CIVIL-MILITARY AFFAIRS)
DIRECTOR OF RESEARCH & DEVELOPMENT
AS/A MP. PERS. AND RESERVE FORCES
AS/A (LOGISTICS)
CHIEF OF STAFF
VICE CHIEF OF STAFF
SECRETARY OF THE GENERAL STAFF
CHIEF COORD GP
CHIEF ANALYSIS GP
DEPUTY SGS
ADMINISTRATIVE ASSISTANT
GENERAL COUNSEL
CHIEF OF PUBLIC INFORMATION
CHIEF OF LEGISLATIVE LIAISON
ASSISTANT CH. OF STAFF FOR RESERVE COMPONENTS
THE JUDGE ADVOCATE GENERAL
THE INSPECTOR GENERAL
ASSISTANT CH. OF STAFF INTELLIGENCE
GENERAL STAFF COMMITTEE OF NAT'T GD. AND ARMY RESERVE POLICY
COMPTROLLER OF THE ARMY
DEPUTY CH. OF STAFF FOR MILITARY OPERATIONS
CHIEF OF RESEARCH AND DEVELOPMENT
DEPUTY CH. OF STAFF FOR PERSONNEL
DEPUTY CH. OF STAFF FOR LOGISTICS
CHIEF ARMY RESERVE AND ROTC AFFAIRS
CHIEF OF SPECIAL WARFARE
CHIEF OF CIVIL AFFAIRS AND MILITARY GOVERNMENT
CHIEF OF MILITARY HISTORY
CHIEF NATIONAL GUARD BUREAU
CHIEF OF INFORMATION
THE ADJUTANT GENERAL
CHIEF OF CHAPLAINS
THE PROVOST MARSHAL GENERAL
CHIEF OF FINANCE
THE SURGEON GENERAL
CHIEF OF ORDNANCE
CHIEF OF ENGINEERS
THE QUARTERMASTER GENERAL
CHIEF OF TRANS-PORTATION
CHIEF SIGNAL OFFICER
CHIEF CHEMICAL OFFICER



ARMY AVIATION

In elevating the military air arm to the status of a separate, coordinate service, the National Security Act of 1947 stripped the United States Army of most of its air power, but not of all its aviation units. The origin that part of its aviation program which the Army kept goes back to 1942 when the War Department made light liaison airplanes organic to specific units of the Army Ground Forces. The number of such aircraft rose to around 1,600 by 1945 but then declined in two years to about 200. The total has since risen, however, to roughly 3,400 airplanes and helicopters.

MISSION. The mission of Army aviation is to aid in the conduct of land operations by improving mobility, command control, and logistic support of Army forces and by providing observation and reconnaissance means. In carrying out its mission Army aviation is governed by a 1957 Department of Defense directive. The directive states that the Army will perform liaison courier and communication tasks (including aerial wire laying); observation, photographic, and fire control flights; airlift of troops and material, and aeromedical evacuation *within* the Army combat zone. The combat zone is defined as an area not more than 200 miles in depth.

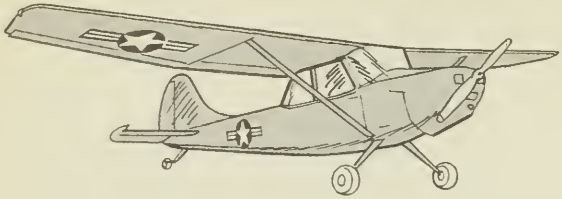
Army aviation cannot perform strategic or tactical airlift, tactical reconnaissance, battlefield interdiction, or close combat support. These are USAF functions. Furthermore, Army fixed-wing aircraft must not weigh over 5,000 pounds (empty), and rotary-wing aircraft not more than 20,000 pounds (empty). The USAF is charged with the airlift of supplies, equipment, and men to and from the Army combat zone and also serves as the carrier in the initial and later phases of airborne operations.

ARMY AIRCRAFT. Army aircraft consist of airplanes (fixed-wing) and helicopters (rotary-wing). Whatever their type, all Army aircraft reflect many design compromises. For example, they must be sturdy but cannot weigh too much; the result inevitably falls short of the ideal. Similarly, their required ability to take off and land in a limited space inevitably cuts their payload capacity.

Army airplanes are classified as (1) observation, (2) command, (3) utility, and (4) utility transport. Observation airplanes are light in weight and used mostly for close-in reconnaissance and combat surveillance. They are simply built and can operate from small, unprepared airstrips. Command airplanes are twin-engined craft assigned to corps or higher headquarters for command, liaison, and courier missions. They normally need improved airstrips. Utility airplanes are multiplace short-haul aircraft. They work at all levels of command and can function from relatively smooth unimproved airstrips. Utility transports have a greater radius of operation, about 550 miles. They can carry 10 fully equipped soldiers or 2,500 pounds of cargo.

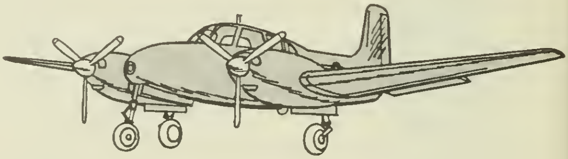
The helicopter outstrips its fixed-wing cousins in versatility. Its speed ranges from zero to about 85 knots. It can operate without a runway. It can move in any direction or just hover. But it does take more maintenance than orthodox aircraft. Army helicopters are classified as reconnaissance, utility, and cargo.

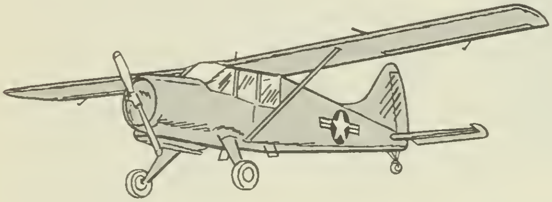
CAPABILITIES AND LIMITATIONS OF ARMY AIRCRAFT. Army aircraft do not function in a vacuum. As they operate they are reacting constantly to such variable factors as weather, terrain, and the enemy. Weather can be a curse or a blessing. Gusty winds near the ground make control difficult, but



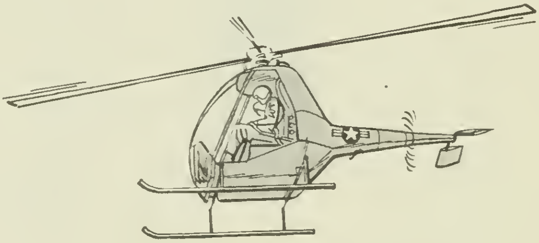
OBSERVATION
Used primarily for close-in reconnaissance and combat surveillance. Cruises at speeds of 80 to 90 knots, but can fly as slow as 45 knots.

COMMAND
Principally used for command, liaison, and courier missions. It can carry four to six passengers and cruises between 130 and 175 knots.

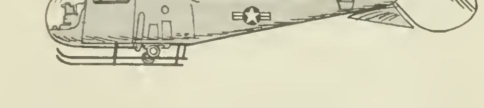




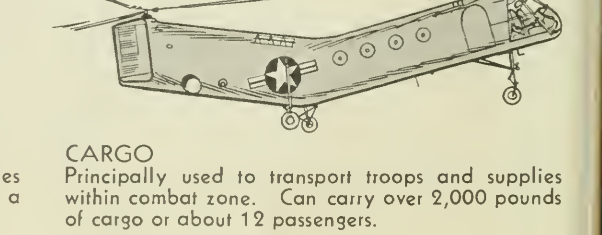
UTILITY
Multiplace aircraft used chiefly for movement of troops and supplies within combat zones.



RECONNAISSANCE Used for combat reconnaissance, courier, and liaison operations. Cruises around 60 knots and has a range about 200 miles.



COMMAND-UTILITY
Serves as a carrier of troops, equipment, and supplies and as a medical evacuation craft. Can carry a pilot and three passengers.



CARGO
Principally used to transport troops and supplies within combat zone. Can carry over 2,000 pounds of cargo or about 12 passengers.

steady headwinds will often provide greater lift. Temperatures also play a part. A rise of 25°F., for example, can reduce a cargo helicopter's lift 25 percent. Terrain is always a vital factor. Rugged terrain can hinder or prevent landings and takeoffs, and make flights difficult or impossible when visibility is poor. But it also has virtues. If hills can endanger, valleys can conceal and protect low-flying aircraft. The enemy's performance may be the most influential factor of all. Army aircraft are extremely vulnerable to surprise fighter attacks. But given warning, they can take effective low-level evasive action against the fastest of modern jets.

ORGANIZATION AND EMPLOYMENT. Army aviation divides into two general categories: aircraft organic to the combat arms, and army transport aviation. Organic aviation usually takes the form of aviation companies assigned to divisions and higher combat echelons. But it may also be organized into sections for duty with lower echelon units.

Combat commanders with organic aviation at their disposal normally can employ it as they wish to accomplish their mission. The possibilities open to commanders are great. They can use organic aircraft for command, liaison, troop combat control, courier service, radio relay, reconnaissance, aerial photography, observation and adjustment of fire, battlefield evacuation, limited resupply, transport of personnel, wire laying, battlefield illumination, and distribution of propaganda.

Army transport aviation takes the organizational form of fixed-wing and helicopter transport companies. Its primary function is combat support; its secondary function, service support. Army transport aviation units are ordinarily assigned to the field, but they may be attached to or employed in support of corps or divisions for specific missions.

Army transport aircraft provide the ground commander with a means of getting more combat mobility. They can circumvent fixed defenses and natural obstacles; they can carry men, equipment, and supplies to otherwise inaccessible areas; and they can land troops at precise points. In short, they can add markedly to the Army's operational capability.

ARMY AIR FIELDS. The Army air fields and Army air bases of the days before the creation of the U. S. Air Force have become for the most part Air Force bases. But the Army still holds on to some airfields in order to carry on its aviation program. Of the 70-odd Army air installations in the continental United States, Pope Army Air Field at Fort Bragg, North Carolina, is perhaps the best known as well as one of the oldest. The list includes municipal airports under lease to the Army, Air Force facilities which the Army uses by special arrangement, and a number of airstrips inside or near regular Army posts.

PERSONNEL. In training its aviation personnel the Army has continued, with appropriate modifications, the basic program that began in 1942 when a school for Army Ground Forces liaison pilots and mechanics opened at Fort Sill, Oklahoma. The school moved to Fort Rucker, Alabama, in January 1955 and has since carried on with greatly expanded facilities. Until recently, the United States Air Force had charge of pilot and mechanic training for Army aviation.

For the most part Army aviators are officers previously commissioned in their respective branches. Generally speaking, pilot training is restricted to lieutenants who belong to branches which have been authorized organic aircraft, or are willing to accept assignment with them.

At present the Army has two aeronautical designations—Army Aviator and Senior Army Aviator. The rating of Army Aviator is generally restricted to qualified officers in certain branches of the service who have completed prescribed flying training courses. A Senior Army Aviator's rating calls for more. To get it an officer must be an Army Aviator (or an eligible equivalent) on flying status; or have been rated as an Army liaison pilot for at least seven years. Secondly, he must have a total of 1,500 pilot-hours flying time or 1,000 hours plus at least six months of overseas service as an artillery air officer in the Second World War. All Army aviators on flying status draw incentive pay at rates comparable to those which apply in the Air Force.

THE FUTURE OF ARMY AVIATION. The Army Chief of Staff, General Maxwell D. Taylor, has declared that the Army "must inevitably move in the direction of new and novel flying machines which will probably be much different in appearance from conventional types we know today." [10] But he has explicitly denied any intention of building Army aviation into another Air Force.

The Army's desire for its own aviation has provoked much criticism because of the duplication and additional costs involved. But clear policy directives from the Department of Defense have cut, if not eliminated, that duplication, and Army aviation today makes a worthy contribution to our over-all military power.

THE UNITED STATES AIR FORCE

The United States Air Force has three major aims: to defend the United States against air attack; to launch a strategic air counterattack against any aggressor; and to give tactical and logistical support to the Army and Navy if war comes. An acute awareness of that three-fold mission lies back of all Air Force thinking and guides the endless process of refining and streamlining the fighting force. All changes in that force have only one end in view—to enable it to carry out its mission with ever greater efficiency and effectiveness.

The Air Force cannot stand still. The world moves fast, and the Air Force must move just as fast or die. Its material, manpower, and other programs must all undergo periodic adjustment to meet new requirements and new possibilities. No one can be certain of the future. But the Air Force must nevertheless anticipate the shape of things to come if it is to continue to meet the needs of national strategy.

Quality is the essential goal of the Air Force. In the air, the margin between victory and defeat may be a few miles per hour in speed, a slight difference in maneuverability, or a better or more reliable electronic tool or gun. It seems likely that research and development hold the key to enhanced quality and future strength. The present security of the United States rests upon advances made in the past. Future security will depend upon what this country, by wise stimulation and support of scientific effort, can devise for the future.

There are engines in the air development program now that will develop 25,000 pounds thrust, and planners talk in terms of even newer and better power plants—ramjet, pulsejet, and rocket types which will develop almost unlimited power. There has been rapid development in the airplane.

The technological advances in propulsion and electronics are also making substantial contributions to the development of guided and ballistic missiles. Work on strategic, tactical, and air defense missiles has moved ahead rapidly, and the pace of progress is likely to increase sharply. Although many of the missiles are still in their development or flight test stages, it will not be long before they become operational. Some guided missile units are already integrated into the regular Air Force structure.

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[10] *Army, Navy, Air Force Journal,* June 1, 1957.

The question of paramount importance confronting the world today is how to avoid the ravages of thermonuclear war. The certain knowledge of the horrible destruction that these nuclear weapons could inflict lends grim urgency to this question. Faced with the terrible possibility of such a conflict, the United States has chosen as a matter of policy to make itself so strong militarily and so well prepared that should it or its allies be attacked, it could launch, instantly, a counterattack which would completely demolish the aggressor. The United States Air Force is the chief instrument of this policy.

But a state of preparedness is not an end in itself. War cannot be prevented by an uneasy and debatable balance of military power, but it may be prevented if the side that wants peace has a clear superiority in weapons. American policy makers believe that as long as the United States has a marked superiority in weapons, and can deliver them, no nation will attack. The ability to retaliate instantly does more than deter; it gives statesmen time to negotiate and erase the tensions which lead to war. The Air Force is constantly increasing its capacity to carry out the national strategy. From its whole arsenal of weapons—ranging from bullets to nuclear bombs—it can choose those best suited to accomplish any given task. It has established, furthermore, a worldwide complex of air bases and as a result is achieving greater operational flexibility than ever before.

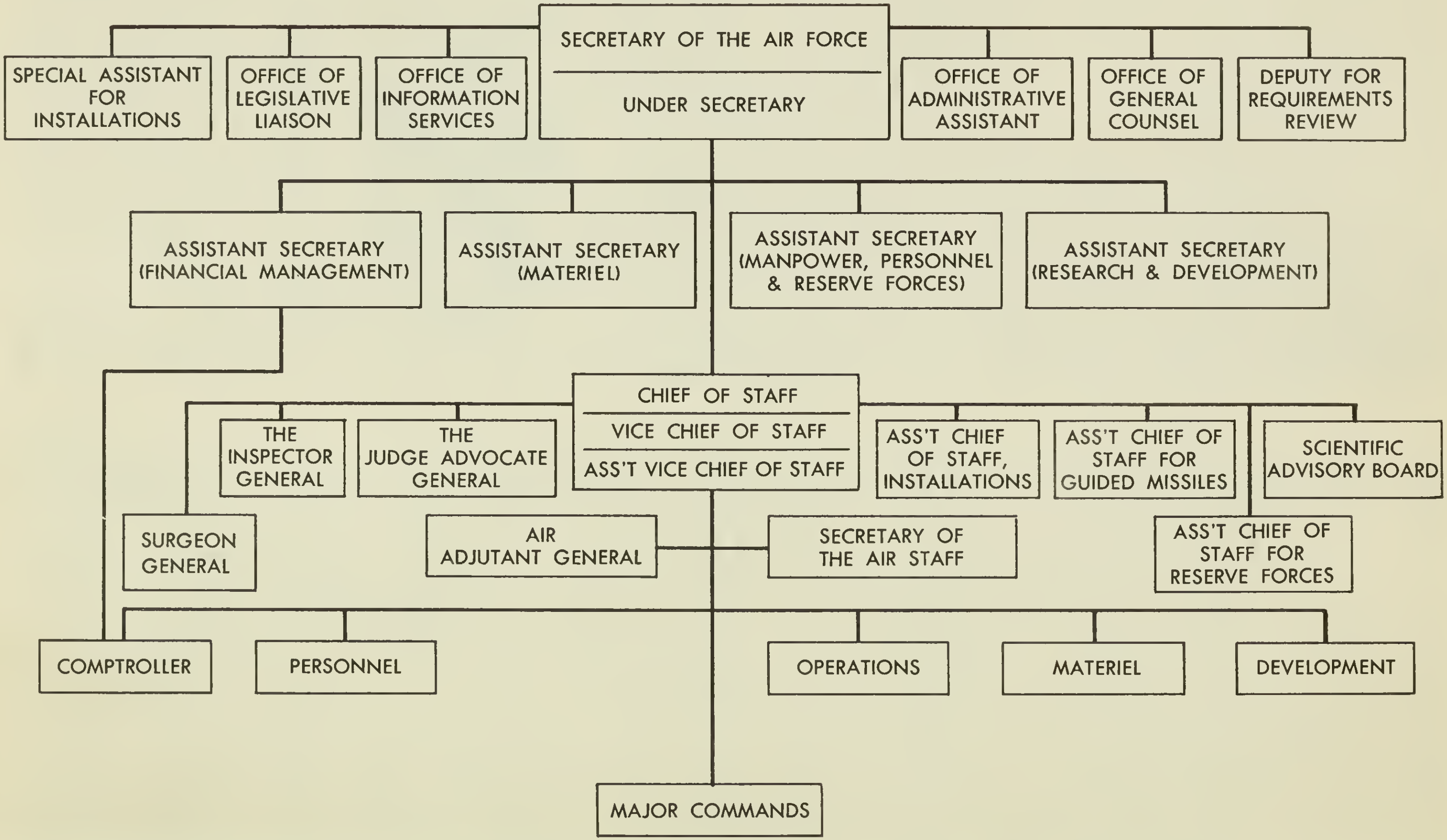
The Air Force realizes that improvement is the key to its survival and usefulness. The drive to improve has reached into every field of activity. It has affected not only weapons, craft, and bases, but also such things as supply, maintenance, and the determination of requirements. The benefits already derived from the effort are notable. Much remains to be done, but the problems are known, and throughout the Air Force there exists the will and the ability to deal with them.

THE USAF IN THE NATIONAL DEFENSE STRUCTURE. During the early years of its existence, the United States could reasonably adopt a policy of isolation and get along without a central military authority. The first half of the present century changed all this. It proved the futility of isolationism in the modern world and provided stark evidence of the need for a tighter, more centralized control of the nation's armed forces. Our isolationism made at least one world war inevitable; our loose military organization gave us Pearl Harbor.

Fortunately, at the time of the disaster of December 7, 1941, we were already at work creating a more closely-knit command structure. By early 1942 both the Combined Chiefs of Staff (which included the British and American ground, sea, and air chiefs) and its purely American offspring, the Joint Chiefs of Staff, were in being and doing great good. Both the CCS and JCS assumed a vital role in directing the global operation of allied armed forces.

Their success and an obvious need led in 1945 to the development of plans by the War and Navy Departments for blending the armed forces of the United States into a unified organization. Each service's plan, however, tended to stress its own role. In 1946, therefore, the President directed the services to reconcile their differences in a joint plan for unification. The result was a compromise set of proposals which supplied the basis for the National Security Act of 1947. That act brought the United States Air Force into being as a third service, independent of and equal to the Army and the Navy. But it also emphasized the interdependence of the three separate services by giving formal status to the Joint Chiefs of Staff and by providing ways and means of achieving greater coordination and unity of effort in national defense matters. The act provided the framework for the present national defense organization. Its detailed provisions will be considered elsewhere in the Air Science course.

DEPARTMENT OF THE AIR FORCE


SECRETARY OF THE AIR FORCE
UNDER SECRETARY
SPECIAL ASSISTANT FOR INSTALLATIONS
OFFICE OF LEGISLATIVE LIAISON
OFFICE OF INFORMATION SERVICES
OFFICE OF ADMINISTRATIVE ASSISTANT
OFFICE OF GENERAL COUNSEL
DEPUTY FOR REQUIREMENTS REVIEW
ASSISTANT SECRETARY (FINANCIAL MANAGEMENT)
ASSISTANT SECRETARY (MATERIEL)
ASSISTANT SECRETARY (MANPOWER, PERSONNEL & RESERVE FORCES)
ASSISTANT SECRETARY (RESEARCH & DEVELOPMENT)
CHIEF OF STAFF
VICE CHIEF OF STAFF
ASS'T VICE CHIEF OF STAFF
THE INSPECTOR GENERAL
THE JUDGE ADVOCATE GENERAL
ASS'T CHIEF OF STAFF, INSTALLATIONS
ASS'T CHIEF OF STAFF FOR GUIDED MISSILES
SCIENTIFIC ADVISORY BOARD
SURGEON GENERAL
AIR ADJUTANT GENERAL
SECRETARY OF THE AIR STAFF
ASS'T CHIEF OF STAFF FOR RESERVE FORCES
COMPTROLLER
PERSONNEL
OPERATIONS
MATERIEL
DEVELOPMENT
MAJOR COMMANDS

USAF RESPONSIBILITIES. The missions and functions of the Air Force, like those of the other services, are assigned by the Joint Chiefs of Staff and approved by the Secretary of Defense. As pointed out before, the Air Force has primary interest in all air operations except naval air operations. It has the chief responsibility for the defense of the United States against air attack and discharges that responsibility in two ways: by destroying invading enemy aircraft, and by delivering retaliatory blows. It also has the decisive offensive task of carrying the war home to the enemy and bombing him into submission. And, in general, it is responsible for gaining and keeping control of the air in vital areas.

Besides being charged with the logistic support and training of its own forces, the Air Force furthermore must furnish logistic and combat air support to the Army. This function includes close combat air support, longer-ranged interdiction operations aimed at the enemy's rear, aerial photography and tactical reconnaissance, and airlift and air resupply during airborne operations. Finally, it usually has to furnish most of the air transport required by the armed forces.

Apart from its primary responsibilities, the Air Force has certain collateral functions assigned to it, such as antisubmarine warfare. But naturally enough the primary responsibilities, rather than the collateral functions, determine the shape of Air Force organization.

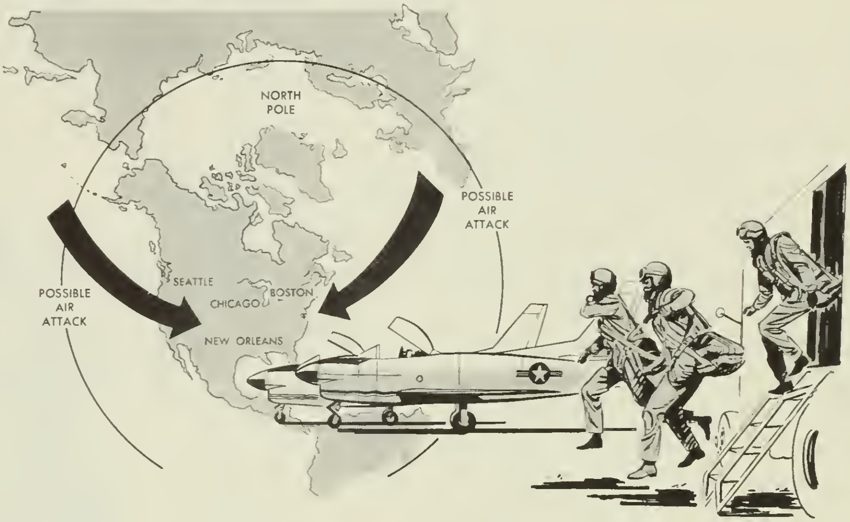
COMBAT AIR COMMANDS. Through its major air commands, the Air Force is organized mainly on a functional basis instead of the geographical basis traditional with surface forces. Functional organization is more suited to rapidly moving air forces deployed on a global scale.

The following brief survey of the major air commands and their functions treats each command separately. This is necessary but the reader should always bear in mind that the commands are interrelated and complementary. They are all different facets of a single thing, air power, and share alike the flexibility that is one of its prime characteristics. As diverse parts of a unity, the combat air commands, for example, can work together or apart according to the need. They can pool their resources for a mass assault at one moment, and then redeploy them rapidly for a series of dispersed but coordinated attacks at the next.

To carry out the mission of the Air Force as a whole, the Chief of Staff of the Air Force has the major air commands assigned directly under his headquarters. Three of these major air commands—the Strategic Air Command, the Tactical Air Command, and the Air Defense Command—are commonly called the combat commands. They were established under the Air Force Organization Act of 1951.

The Strategic Air Command is the long-range striking arm of the Air Force. Once the orders go out from Command Headquarters at Offutt Air Force Base, Nebraska, it can reach out to the enemy's homeland and bomb his long range air force bases and nuclear installations, in order to minimize or destroy his striking power. National survival requires that a favorable decision be attained against an enemy's long range air forces in an all-out war. SAC is also capable of attacking such objectives as industrial complexes, communications centers, sources of power, and stockpiles of strategic materials until the enemy is no longer able to wage war. It must also be prepared to attack tactical targets, if need be.

With its array of B–36's, B–47's, B–52's, B–58's, support fighters, tankers, nuclear bombs, and superbly trained crews, the Strategic Air Command is the most powerful fighting force that history has known. It can go virtually anywhere at unprecedented speeds and inflict blows of unparalleled destructiveness. And, as it takes under its wings the new Intermediate Range Ballistic Missiles and Intercontinental Ballistic Missiles, its power of ruin will increase immeasurably.



The Tactical Air Command is based in the continental United States and has its headquarters at Langley Air Force Base, Virginia. At present the main difference between TAC's forces and those of Strategic Air Command is largely a matter of range. Elements trained by the Tactical Air Command are deployed to overseas theaters where they are assigned to the theater commander. Tactical air forces can also, by using aerial refueling, cooperate with strategic air forces to perform a global mission. In addition, they can support the Air Defense Command in case of an air attack on the United States.

With their present range, speed, and striking power, aircraft of the Tactical Air Command will continue to cooperate closely with land and naval forces, but they will operate over a much wider area. With nuclear weapons and aerial refueling, the fighter-bombers and light bombers of the Tactical Air Command can act as a powerful deterrent, and they are prepared to move instantly to any region of the globe where trouble develops. They can supply themselves anywhere for a time and operate from far less elaborate facilities than those required by heavier aircraft.

TAC's functions include troop carrying and air supply. Its troop carrier units are well-trained in global operations and are prepared to operate in the arctic or in the tropics. They have flown, for example, vast tonnages of materials to Alaska and northern Canada for the DEW Line air defense warning net.

The Air Defense Command, which is part of the joint Continental Air Defense Command and the Canadian-American North American Air Defense Command, defends the United States against air attack. Its headquarters are at Ent Air Force Base, Colorado.

To carry out its mission, ADC relies for warning on an extensive network of radar stations, into which are integrated all types of wire and radio communications and the network operated by the Ground Observer Corps.

For purposes of easier aircraft recognition, the command has established a number of air defense identification zones. These lie along the boundaries of the country and in the vicinity of vital areas in the interior. All aircraft intending to fly through a coastal zone, or above 4,000 feet in an interior zone, must file flight schedules well in advance. The flight schedules are correlated with aircraft tracks picked up by radar and the Ground Observer Corps. When aircraft cannot be identified as friendly, fighters are scrambled to intercept them and establish their identity. All-weather supersonic interceptors armed with rockets now perform this function daily.

For close-in defense of large population centers and industrial and military targets, the Army Antiaircraft Command maintains heavy gun and guided missile installations.

SUPPORTING COMMANDS AND OVERSEAS COMMANDS. These commands will be only mentioned here, as a more detailed treatment of them appears elsewhere in the AFROTC curriculum.

The *Air Materiel Command* provides a system for procurement, production, maintenance, and supply for the United States Air Force.

Through its Air Proving Ground it also develops improved operational techniques and, by carrying out tests under simulated combat conditions, determines the operational suitability of material and equipment used by, or proposed for use by, the Air Force.

The *Air Research and Development Command* is responsible for the discovery, development, and evaluation of qualitatively superior means for accomplishment of the Air Force mission. It undertakes research and development programs necessary to provide new and improved weapon[11] systems, equipment, and techniques for the Air Force.

The *Air Training Command* provides individual training for Air Force officers and airmen. Its program includes recruit basic training and indoctrination, flying training, and training of all ground crewmen, technical specialists, and administrative personnel. The Air Training Command is also responsible for USAF recruiting and the training of certain air crews.

The *Air University* is primarily concerned with the higher education of Air Force officers. It is responsible for the supervision and operation of the Air War College, the Air Command and Staff College, the USAF Institute of Technology, the USAF School of Aviation Medicine, the Research Studies Institute, the Extension Course Institute, and the Air Force ROTC program.

The *Continental Air Command* discharges within the continental United States the field responsibilities of the Chief of Staff, USAF, with respect to the Reserve Forces of the Department of the Air Force (including supervision and inspection of the Air National Guard of the United States), domestic emergencies, and miscellaneous continental administrative functions.

The *Headquarters Command, USAF,* provides miscellaneous services as directed by Headquarters, United States Air Force, including air transportation not available through Military Air Transport Service, and administration of the United States Air Force Band, Air Attache and Air Mission Units, field extension units, and other special mission personnel both in the continental United States and overseas.

The *Military Air Transport Service* is operationally responsible to the Chief of Staff, USAF, although the command includes personnel and other resources from both the Air Force and Navy. It operates on a worldwide basis and provides airlift for the three services as directed by higher authority. In addition, it furnishes weather, communications, rescue, photographic and charting, and flight services for the Air Force as directed by Headquarters, USAF.

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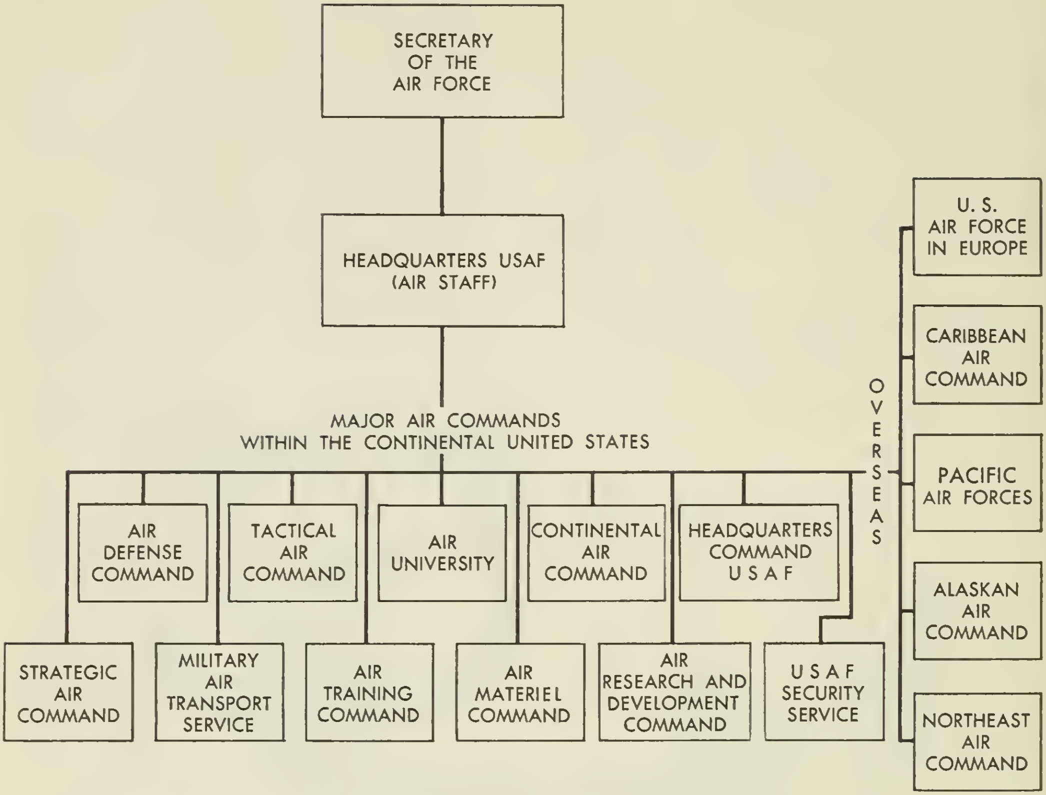
[11] An *air weapon system,* in the broad definition, is an instrument of combat such as an air vehicle, together with the functioning equipment, skills, and services required to enable the instrument of combat to be a single unit of striking power.

MAJOR AIR COMMANDS



The U. S. Air Force has sixteen major air commands consisting of three combat commands, eight supply commands, and five overseas commands.

The *United States Air Force Security Service* is responsible for communication intelligence and communication security activities of the United States Air Force.

The United States Air Force in Europe, Pacific Air Command, and Caribbean Air Command constitute the major overseas commands of the USAF. They are responsible for the bomber, fighter, transport, and logistic functions in their areas of operations. Further, they provide air strength for the joint or combined forces to which they are assigned and assist air forces of other countries as directed by higher authority.

Below the level of the major air commands are the following echelons of command in descending order: the numbered air force, the air division, the wing, the group, the squadron, and the flight. A brief outline of these intermediate and lower echelons is given here to show the pattern of Air Force organization.

When a major air command is subdivided into numbered air forces or their equivalents, the breakdown is made either according to geographic areas or functions. Strategic Air Command is a functional command, but it is subdivided geographically. The same applies to the Air Defense Command whose subdivisions are even more clearly geographical in nature. Tactical Air Command and the Air Training Command by contrast, have their subordinate air forces organized according to functions. Usually there are two or more air forces under a major air command. The numbered air force corresponds to the numbered army of the U. S. Army.

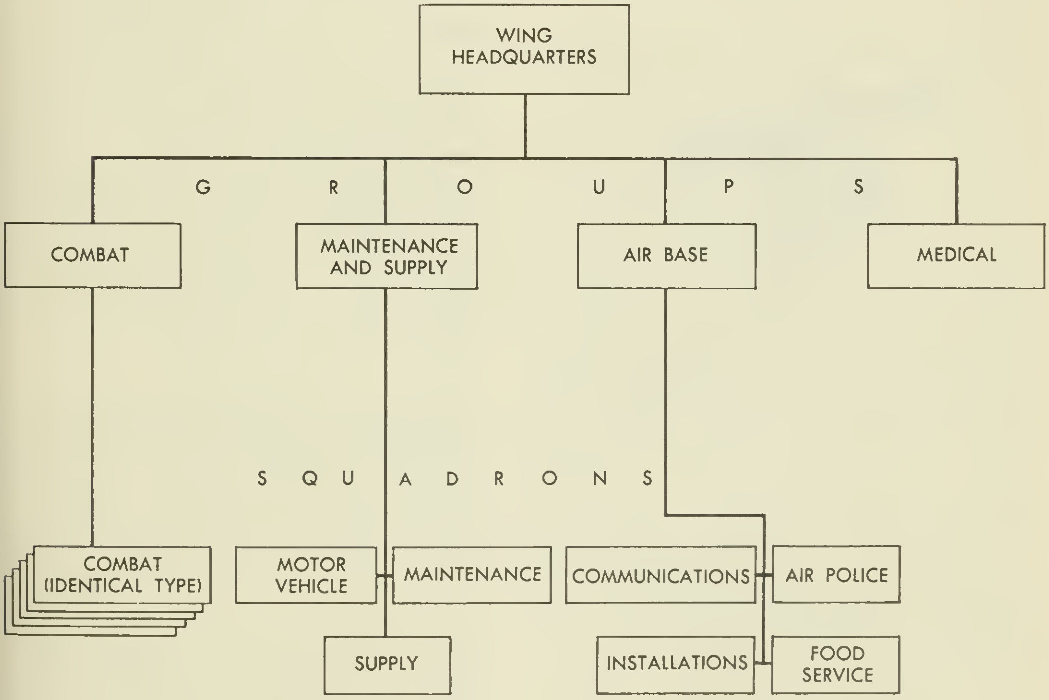
Usually the air division appears in a tactical organization. When the air division is used, there are two or more under a numbered air force. The air division is the Air Force equivalent of the Army division.

The wing is the basic unit of Air Force organization. It is the lowest echelon of command that can operate independently for any length of time. The wing integrates all the elements needed for performing a mission and operating a base. The combat wing is the organization usually designated to direct the actual employment of air power. Many noncombat wings use a standard combat wing-base as a guide for their organization. This wing-base consists of a headquarters and the following four groups: primary mission (combat, transport, training, etc.), maintenance and supply, air base, and medical. Usually there are two to five wings under an air division. The wing is comparable to the Army's brigade.

When a wing contains more squadrons than can be controlled by one headquarters, the squadrons are placed in groups according to their function. A wing usually has four groups. The group corresponds to an Army regiment.

The squadron is the basic tactical and

TYPICAL TACTICAL COMBAT WING



The typical combat wing is made up of a headquarters, a combat group, a maintenance and supply group, an air base group, and a medical group.

administrative unit. It may operate independently for a time, but it usually has to function as part of a group. It may be an organization that either does or does not fly. Normally there are two or more squadrons to a group. The Air Force squadron corresponds to the Army battalion.

The flight functions as a detachment of a squadron or as a unit with its own authorization. There are two or more flights in a squadron. The flight is comparable to an Army company.

AIR RESERVE FORCE. Up to 1958 approximately 80 percent of all Air Force officers on active duty were Reserve officers. The Korean War emphasized the importance of an adequate Air Force Reserve. The presence of large numbers of reservists in its ranks, and the rapid influx of many more from civilian life, enabled the Air Force to seize and hold control of the air over the battlefield in support of hard-pressed UN ground forces.

The benefits thus reaped by the Air Force and the nation in Korea were all the more remarkable in the light of the painfully slow development of the Reserve between 1945 and 1950. After World War II a requirement of 146,000 reservists was set for organized units—groups and squadrons training with aircraft. The Reserve received an authorization of 130 bases, but by 1947 only 70 were active. Much of the flying training was in outmoded aircraft and therefore had only limited value for reserve bomber and fighter pilots. Economy moves soon cut the number of reserve bases to 41, and by 1948 there were only 23 remaining.

Although followed by discouraging stop-and-go planning, a study by the President's Air Policy Commission in 1948 did much to ready this country for Korea.

From its large pool of reserve flying officers, the Air Force recalled thousands to active duty for the Korean emergency. In contrast, only 700 pilots were on call at the beginning of the Second World War.

The nature of modern conflict now requires an Air Force Reserve which must be better equipped, trained in more skills, and more adequately prepared than ever before. In an endeavor to meet this responsibility, Congress in 1951 formalized the over-all organization authorized by the Unification Act of 1947 as follows: "The USAF shall consist of the Regular Air Force, the Air Force Reserve, the Air National Guard . . ." The Armed Forces Reserve Act of 1952 further defined the Guard and Reserve.

The mission of the reserve components of the Air Force is to provide trained units and qualified individuals to be available for active duty in the USAF when needed. The Air Force Reserve and the Air National Guard of the United States are the two reserve components of the Air Force. All officers and airmen of these organizations are USAF reserve personnel. The following discussion will acquaint the reader with the way in which the reserve components fit into and support the active USAF establishment.

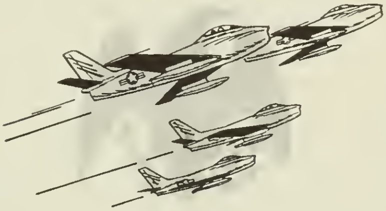
The Chief of Staff, USAF, under the direction of the Secretary of the Air Force is responsible for all reserve matters. Within the Air Staff, the Chief of Staff has delegated general authority for coordinating and monitoring reserve activities to the Assistant Chief of Staff for Reserve Forces. In addition he has made the deputy chiefs responsible for handling reserve questions that fall within their areas of jurisdiction.

Field responsibility for the Air Force Reserve largely rests with the Continental Air Command. The Commander, Continental Air Command, through his numbered air force commanders, controls the organization, training, support, and administration of the Air Force Reserve and supervises the training and inspection of the Air National Guard. Permanent party support organizations, acting under the authority of the numbered air force commanders, conduct the organic administration, support, and training of the reserve units. Responsibility for individual reservists holding mobilization assignments belongs to the major Air Force commands with which they are affiliated.[12] Each major command takes care of the administration and training of reservists holding these assignments.

The *Air Force Reserve* includes all air reservists except those who are members of the Air National Guard. Certain Air Force Reserve units and positions are designated Ready. The Ready Reserve is that part of the reserve component of the Air Force that may be immediately called to active duty in an emergency declared by the Congress, proclaimed by the President, or otherwise authorized by law. All reservists not assigned to Ready Reserve units or positions are designated Standby Reservists, unless they are retained in the Ineligible Reserve Section or in the Retired Reserve Section.[13] The Standby Reserve is the part of the Air Force Reserve that can be called to active duty only in war or by Congressional action. Each Air Force reservist has a personal status as a Ready Reservist, a Standby Reservist, or a Retired Reservist.

Aircraft required by the Air Force Reserve reach it as a result of the process of modernizing regular Air Force units. As new aircraft come into service, the older aircraft they displace are transferred to the Reserve. Air Force Reserve units are equipped on the same basis of authorizations as are units of the active Air Force. Training equipment peculiar to the requirements is authorized and provided in addition to authorized unit equipment. At the end of Fiscal Year 1955, the Air Force Reserve had 732 aircraft, 327 of which were jets.

The Air Force Reserve Individual Training Program has the objectives of providing qualified individuals to meet the USAF-wide mobilization requirements for augmentation, attrition, and replacement. The basic concept is that all paid reserve personnel will train against the mobilization requirement. The training requirement is determined by the proficiency of the reservists slated to fill the mobilization positions. Active duty tours normally provide on-the-job training in the mobilization assignment. However, resident school courses are available when such training is required. All reservists interested in furthering their military knowledge and education can also take correspondence courses.



The *Air National Guard,* as has been previously indicated, is a reserve component of the USAF. It is composed of federally recognized units, organizations, and persons appointed and commissioned in the ANG of the various states, territories, and District of Columbia. The President may call all or any part of the Air National Guard into active federal service whenever needed. In June 1954 the Air Force and the National Guard Bureau reached an agreement regarding Air National Guard units not in federal service. Under the terms of the agreement, USAF Headquarters would make the final decisions and the National Guard Bureau would issue the necessary directives to the units.

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[12] A *mobilization assignment* is an assignment of an Air Force Reservist to a specific position provided for in an active Air Force organization by Hq USAF, which position affords inactive duty training to the reservist before mobilization, and a place for assignment to active duty upon mobilization.

[13] The Ineligible Reserve Section consists of those Ready Reservists who were transferred to the Air Force Reserve to complete a reserve obligation in accordance with the Universal Military Training and Service Act of 1948, as amended, and who do not voluntarily participate in reserve training programs. Members of the Retired Reserve are those individuals whose names have been placed on the USAF Reserve Retired list.

Air National Guard personnel receive training from their various units and from service schools of the active military establishment. Unit training is accomplished at unit training assemblies, at annual field training periods, and through special exercises. School training is accomplished at various service schools available to personnel of the Air National Guard. The formal school training program for the Air National Guard uses schools of the regular Air Force establishment that provide technical and professional training beyond the capability of the Air National Guard units. After receiving such schooling, Air National Guardsmen return to their home units and in training classes pass on what they have learned.

As of June 30, 1955 the Air National Guard had 2,054 aircraft on hand. This was 70 percent of the 2,979 aircraft authorized under the 27-wing Air National Guard program. Of the total aircraft on hand, 1,097 were jet-fighters—F–80's, F–84's, F–86's, F–89's. All Air National Guard fighter squadrons that had adequate runway facilities were by then jet-equipped.

One of the most significant developments in the history of the Air Reserve Forces Program occurred during the period January 1—June 30, 1955. It was the establishment by the Chief of Staff of a firm mobilization requirement for the Air Force Reserve and the Air National Guard, with both components directed to attain an acceptable degree of combat capability at the earliest practicable date. All later actions and policies have been geared to that concept, and a broad revitalization program is now in progress. The Air Reserve Forces are receiving encouraging recognition and support as significant constituents of our country's defense system.

SUMMARY. With the development of jet aircraft and nuclear weapons of vast destructive power, air power has gained a decisive advantage. As a result, it has radically changed the conduct of war and the conditions of national security. Without a large air force in-being, the United States could neither retaliate in case of air attack nor bring the war to a successful conclusion by striking the enemy's homeland.

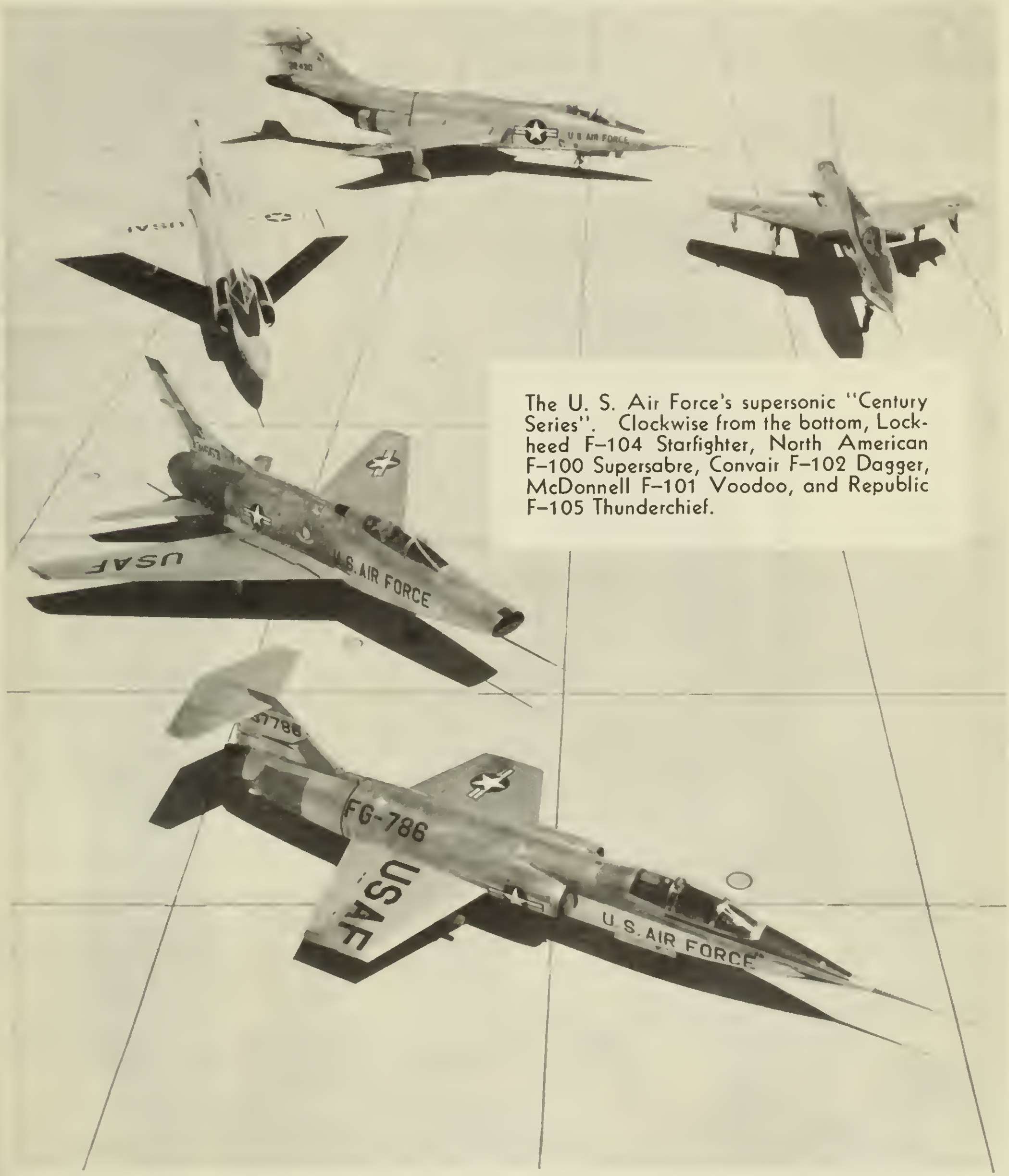
Because of the need for air power, the United States has built up its Air Force rapidly. During some 50 years the Air Force has grown from an Army Signal Corps unit, consisting of one officer and two enlisted men, to the status of an independent service. It already has a record of great achievement, written in two world wars and the Korean conflict; and its future possibilities as an instrument of national defense policy appear unlimited.

Today the Air Force is administered by a civilian secretary, and its operations are supervised by the Chief of Staff, assisted by the Air Staff. It has the primary interest in all operations in the air except naval air operations. It defends the United States against air attack, and it is responsible for launching a counteroffensive against the aggressor. It also is charged with giving logistic and combat air support to the Army.

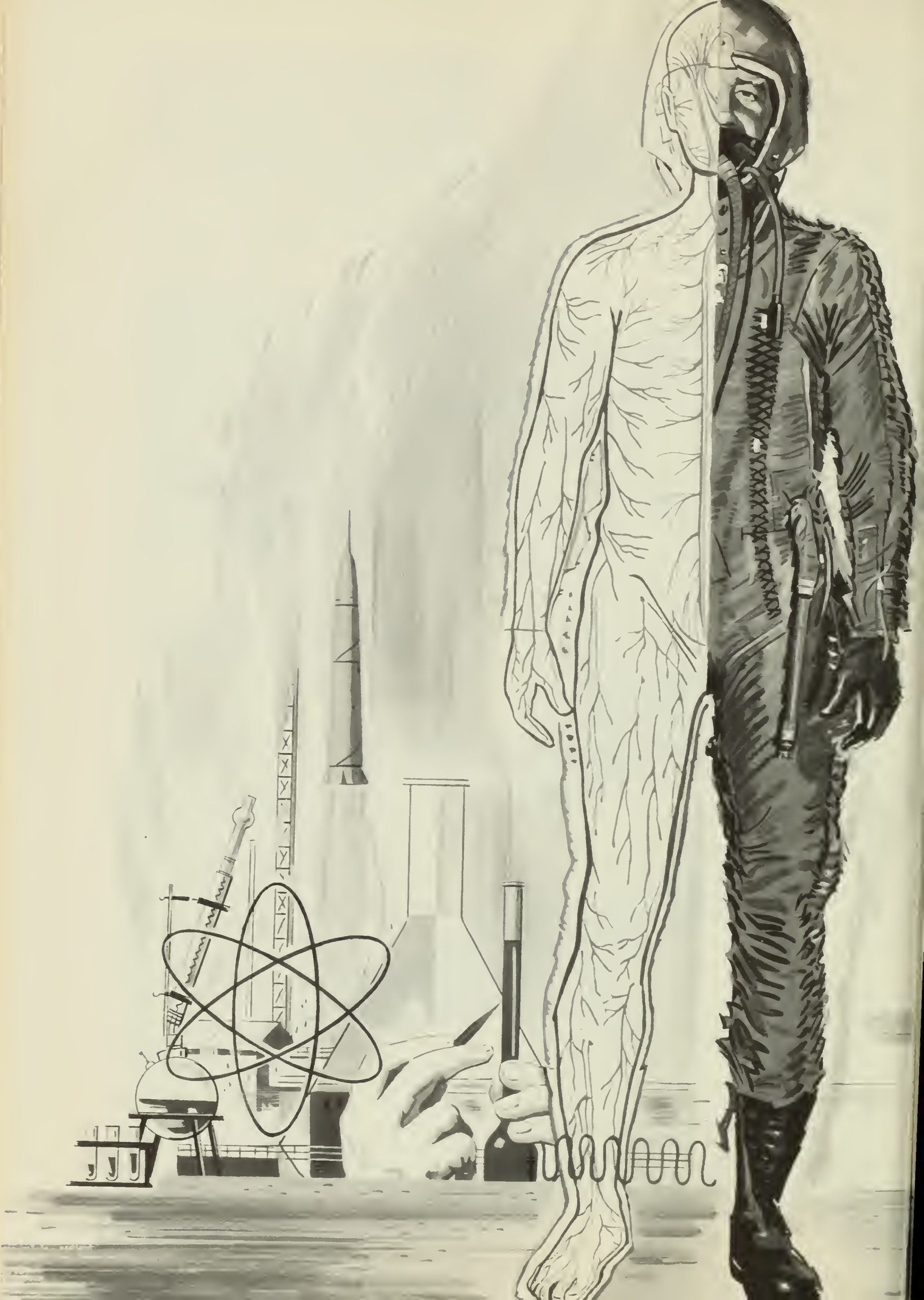
To carry out its mission, the Air Force is organized primarily on a functional basis, a type of organization suited to rapidly moving air forces deployed on a global scale. This functional division does not, however, destroy the unity of the Air Force. The different functional commands supplement each other.

The combat power of the Air Force resides in the Strategic Air Command, the Tactical Air Command, the Air Defense Command, and the overseas air commands. To give these commands a critical edge in quality over its potential foe, the United States strives constantly to supply them with the best new weapon systems that the Air Research and Development Command, and the Air Materiel Command, can design, test, and procure. Maintaining and operating this top-quality equipment are personnel trained and educated by the Air Training Command and Air University. The Military Air Transport Service provides air transport for all the services on a worldwide basis. Within the United States, Continental Air Command exercises jurisdiction over the Air Reserve Forces and performs other administrative services. The Air Force Security Service and Headquarters Command, USAF, are service organizations.

Behind this active duty Air Force stand the Air Force Reserve and the Air National Guard of the United States, both of which have already rendered invaluable service to the nation in time of crisis and are preparing to do so again should the need arise.



The U. S. Air Force's supersonic "Century Series". Clockwise from the bottom, Lockheed F–104 Starfighter, North American F–100 Supersabre, Convair F–102 Dagger, McDonnell F–101 Voodoo, and Republic F–105 Thunderchief.



PART 1

CHAPTER 3

Air Research, Development, and Procurement

RESEARCH AND DEVELOPMENT

It is generally believed that the chances of preventing another war are in direct ratio to the military strength of the United States. If the United States remains strong enough to deal instantly and effectively with any act of aggression, would-be attackers are not ikely to commit such acts. The military strength of the United States today depends for the most part on the quality of the nation's air arm. The air arm in turn depends heavily on the quality of ts research and development program, for only if that program functions imaginatively and efficiently will there be available the advanced weapon systems needed to deter or destroy aggressors. These new weapon systems must grow out of achievements in pure and applied science. That is why there has to be a close coupling of military research and development with progress in science and technology.

Research and development in the broad technical fields now encompassed by aerial weapons systems is one of the most important aspects of the USAF and the nation's security. It provides significant returns for the taxpayer. In the first place, it can bring forth aerial weapon systems of sufficient superiority to deter any potential aggressor. In the event the deterrent fails, those same aerial weapon systems will help decisively to insure military victory over the aggressor. Finally, progress in research and development will have a fruitful effect on the nation's industry and general economy.

A critical phase in the air research and development program has now been reached. This country is confronted by the gravest challenge it has ever known. Our potential enemies are bent on using military might to promote the spread of their tyranny, and they are therefore working day and night to outstrip us in the air. This, coupled with the disturbing fact of their rising scientific skill, has forced our civilian and military leaders to take drastic action.

To meet the challenge, the Air Force has put a heavy stress on the activities of the Air Research and Development Command. The stress is likely to increase greatly in the coming years. This chapter will deal largely with the way in which ARDC has molded its unique military-industry-science partnership, and the policies and factors which guide its work.

Under the pressure of world crisis, expenditures on our research and development program have soared from about $29,000,000 in fiscal year 1940 to about $2,050,000,000 for fiscal year 1956. The effective organization of this program requires the constant integration of military with civilian skills. The gains cannot be measured in dollars and cents; they must be measured in terms of the defense of the United States.

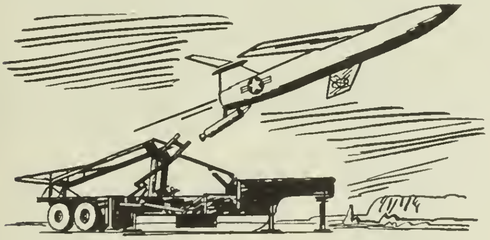
Before the Second World War the research and development activities of the Army and Navy were at an extremely low level. Money was limited, and therefore activity and results were also limited. This situation was probably an important factor in the creation by the President in June 1940 of the National Defense Research Committee, a civilian organization with authority to initiate, and funds to support, research and development directed at creating new weapons.

This was indeed a most constructive and essential step toward an immediate and effective application of science and technology to the art of war. The talents and resources were available. In the period after the First World War the scientific strength of our country had grown enormously. The number of universities engaged in research in the physical sciences had increased several fold, and there had been a corresponding increase in American contributions to scientific knowledge. American industries had created a dynamic technology directed at applying the new knowledge. If this country was to create with speed advanced techniques and weapons, then the civilian scientists and engineers, and the research and development establishments of our universities and industries had to be employed.

In 1941 the Office of Scientific Research and Development superseded the National Defense Research Committee. The scope of the new organization was greater than that of the old. Throughout World War II it was the leading agency in the field of civilian scientific and technological effort. As the war progressed the Army and Navy rapidly expanded their own organizations for research and development. In addition to their close and increasingly effective cooperation in the programs begun by the Office of Scientific Research and Development, the Army and Navy undertook their own programs, which were largely carried out in industrial laboratories. The combined effort of the civilian and military organizations yielded a rich harvest in the ways and means of waging war.

By the close of the war we were superior or equal to the Germans in the weapons of that day. We had also, with the cooperation of our British and Canadian allies, created the atomic bomb. Only in certain areas of advanced weapon development did we lag behind our enemies. As part of the general and rapid demobilization of the armed forces, the Office of Scientific Research and Development went out of existence in 1946, and its programs were assigned to the Army and Navy for disposition. The two services set up the Joint Research and Development Board to coordinate all their research and development programs. After the USAF came into existence, the task of coordinating the programs of the three defense departments was assigned to the Research and Development Board, which was made part of the office of the Secretary of Defense. In the new Department of the Air Force, a special assistant to the Secretary received charge of the coordination of air research and development matters. Actual operations came under the Air Research and Development Command.

The research and development difficulties that plagued the Air Force in this postwar era of economy-mindedness were many and diverse. There was much to be done and the means were often less than adequate. The problems arose in part from the nature of the work. It was fantastically complex, took time, required steady effort, and once cut back could not be resumed without great trouble.



The following story of the Martin Matador will give some insight into the complexities and problems involved in the development program.[1]

After World War II in Europe was over and our field officers had had a chance to look closely at the German installations, they were quite impressed by the enormous possibilities of the science of guided missiles. They studied performance figures of existing missiles and began to send back suggested specifications for American firms to work on. One of these specifications triggered the design competition for the weapon system that since has become known as the "Matador". In August, 1945, the list of desired properties for a ground-to-ground missile was submitted to U. S. aircraft manufacturers. A number of companies prepared proposals covering a wide range of configurations to accomplish the desired performance.

After looking over these proposals, the Air Force placed thirty contracts with several companies in March, 1946. These preliminary design studies were to be completed by January, 1947. The Air Materiel Command evaluated them and in August, 1947 a development contract was awarded to the Glenn L. Martin Company of Baltimore, Maryland. Although engineers considered a number of configurations during the preliminary study period, only one design was submitted for the final evaluation. This original plan called for all the additional assemblies necessary to fly the missile, including the zero-length launcher. One of the primary Air Force requirements was that the new missile be economical to construct and simple to maintain. Therefore, the Martin program was based on the use, so far as possible, of stock items. For example, a production engine, the Allison J–33, was selected. An existing internal guidance system was used in the original version.

In December, 1947 fabrication of the first missile started. This experimental model was completed in June, 1948 and delivered to the field in October, 1948. While this was going on, the other assemblies and components were being built by various sub-contractors. Union Switch and Signal was given the job of building a mobile zero-length launcher on a flat bed trailer. For the early test Martin constructed a heavy fixed launcher at Aberdeen Proving Grounds. This was used to test ten dummy Matadors during 1948. In January, 1949 the mobile launcher was delivered to the field. The test that followed proved that the basic airframe was flyable, that the zero-length launch technique worked. Since the early Matadors had been built for experimental purposes, they had a number of drawbacks from the production standpoint. For instance, the fuselage had double curvature all along the way which made for difficult fabrication. From a field maintenance standpoint, such features as the mid-wing design were undesirable. The wing had to be carefully slid into a hole in the fuselage and then secured with over 70 screws. As the experimental program continued, the usual quota of "bugs" began to appear. One was that the missile suddenly spun in during a level flight. It turned out the fuel tank pressure release valve failed at altitudes over 30,000 feet. At high altitudes, fuel consumption without pressure relief caused the fuel tank to collapse. This in turn smashed the vertical gyro which was located just behind the tank. The solution was to substitute a new kind of valve. In another test flight the power plant quit and the missile failed in the terminal dive. This time the intake duct had collapsed completely during the dive. The structure was changed again and this solved the problem.

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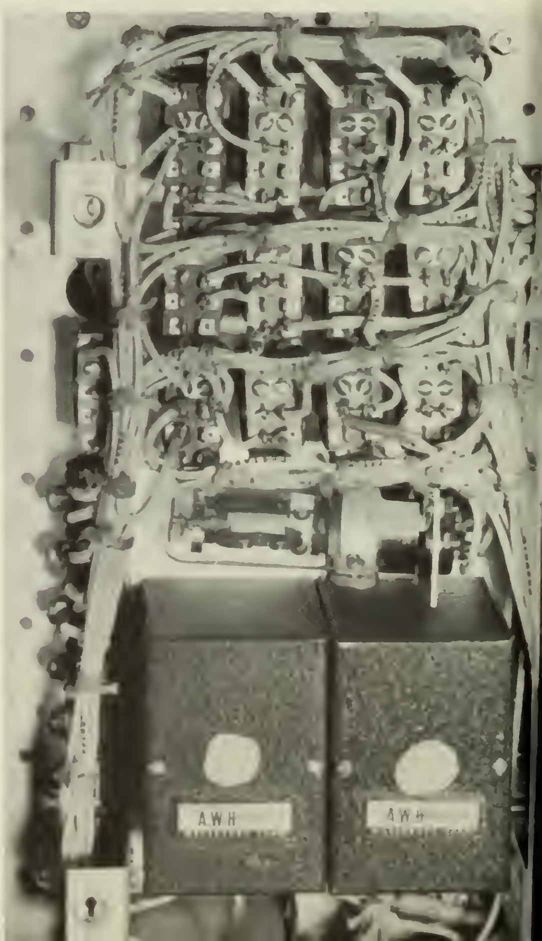
[1] Reprinted from "Birth of a Missile," *Aviation Age,* Vol 23 (June 15, 1955), by permission of Conover-Nast Publications. Copyright 1955.

The test program continued throughout 1949 but late in that year it was curtailed due to fund cutbacks. Work continued on a reduced level. By the middle of 1950, at the outbreak of the Korean War, the Matador had not yet been fully developed. Despite this, it was decided to start an accelerated program to get a production version of Matador as quickly as possible. Even more than the original design, the production version had to be inexpensive and easy to maintain in the field. This redesign replaced the fuselage double curvature and more easily produced single curvature throughout. The wing was made a shoulder type so that it could be easily placed in position and fastened with fewer bolts. The missile was also divided into seven sections for ease of assembly and to facilitate shipping. The entire structure was simplified as much as possible. The performance requirements for the production model were also changed. This increased the gross weight which made it necessary to develop a new booster rocket to supply more thrust for takeoff.

While the production redesign program was getting under way, tests were continued with later models of the Matador. Originally all turns were flat ones and used the rudder, but this meant the missile couldn't stabilize quickly enough in a roll. In 1950 the rudder was eliminated to make all turns coordinated ones. This also made it possible to use a simplified autopilot. The 1951 test program demonstrated that the elevators could not control extreme conditions of push-over and dive. Therefore, a new, all movable horizontal stabilizer was installed. The stabilizer was also changed from a straight surface one to one with dihedral.

Close-up of the engine control circuits in the Matador. Literally miles of intricate wiring and complex circuitry go into the missile's design.

U. S. Air Force Photo



U. S. Air Force Photo

One of the many "bugs" which the Matador's designers had to solve was proper location of components and units, such as the hydraulic transfer valve shown above.

Air Force Matador being raised to firing position by an Air Force launch technician who is operating its hydraulic elevator controls. Through improvements in the guidance system, this model of the Matador was made more highly resistant to enemy electronic counter-measures than were earlier models. It flies more than 650 mph. at altitudes above 35,000 feet.

U. S. Air Force Photo

The first launch of the Matador was in November, 1952. The test failed—the booster rocket nozzle flew off. The nozzle was redesigned and the first successful launch took place in January, 1953. During the 1953 test, a new difficulty arose. The missile broke up in the terminal dive phase of its flight. It was thought that this wouldn't occur if the Matador's speed could be kept out of the narrow band of transonic speeds. The first attempt to solve the problem was to devise a means of slowing the missile down as it entered the dive so that it wouldn't exceed the critical speed. A drag parachute was attached to the tail to open just as the dive phase began. The second attempt consisted of setting the engine at full speed as the dive started so that the speed would be kept above critical. However, neither method was effective.

In 1954 it was finally decided to strengthen the structure to prevent failure at the high dive speeds. Stronger vertical fittings were used in the tail. The linkages in the horizontal stabilizer control and the wing fittings were also beefed up. Another change involved straightening the upper aft end of the fuselage to reduce the venturi effect between the tail and the fuselage. With the solution of the terminal dive problem, the last major obstacle in the Matador development program was overcome. By mid-1954, the USAF was ready to set up its first operational Matador unit.

How a Weapon System Is Planned

Today, the first step in planning a weapon system is to determine a need for it in Headquarters USAF. This involves a consideration of national policy, military strategy and tactics, war plans, and also the capabilities of the potential enemy. The Office of Development Planning of the Air Staff performs this function. Working with the Air Research and Development Command, it evolves a development planning objective which describes the capabilities of the air weapons required to support basic combat missions of the Air Force. The planners have to look five to fifteen years into the future.

Once the general objective has been stated, the next step is to become more specific by issuing a General Operational Requirement (GOR). This document spells out the operational need for a weapon in the fulfillment of a specific mission. After receiving the GOR, Air Research and Development Command reviews it and establishes development policy and guidance in the various technical areas to be explored in the process of fulfilling the requirement.

The next phase is the actual development. This is done essentially through weapon system contracts. The weapon system contractor is responsible for the complete engineering integration of all the components of the system. He talks to people who will use it about manner of use, bases, operational environment, kind of bombs, type of tactical control, and so on. In his relations with the Air Force, he is governed by its policy of not allowing public funds to be spent in a way that will give a weapon system contractor an unfair advantage over his competitors. Public funds, the Air Force feels, should not serve to weaken competition.

In shaping its research and development philosophy the Air Force has to take into account trends in international relations and many other factors. It must always avoid short-term palliatives that solve nothing, but seek instead programs that will have validity for more than a day. As former Secretary of Defense Charles E. Wilson put it: "Our permanent policies cannot be based upon the simple summation of all the possible emergencies we face, nor can our forces be calculated by the simple addition of all of our forces necessary to meet all possible emergencies simultaneously. Emergency measures are superficial. They are costly in both manpower and resources. We must have long-range plans and be able to take the initiative if necessary."

Advances in the field of research and development are now coming so rapidly that keeping ahead of potential enemies in the race for better weapons calls for a continuous, well-organized, and extensive program. Modern arms are complicated mechanisms that require in their development the cooperative effort of many highly skilled specialists.

U. S. Air Force Photo

Huge RCA electronic microscope used in the pathological department at the School of Aviation Medicine, Randolph Air Force Base, Texas. Capable of multiplying objects 700 times their normal size, the microscope is typical of the new scientific instruments which are enabling flight surgeons and scientists to make great progress in aeromedical research.

The successful takeoff, flight, and landing of a robot plane stirs the imagination to thoughts of a new age in warfare. But usually there is little realization of the number of developmental steps leading to the plane's flight. Those steps are absolutely essential. Without them there would be no flight. Behind every new weapon, aircraft, missile, or other device is an idea or series of ideas which must undergo infinite refinement and improvement before anything militarily worthwhile can come of them.

The Speed-Up of Technical Progress

Surrounded by speed, caught up by it, one overlooks the rapidity with which great changes are happening. Atomic energy, with its tremendous impact upon the future of mankind, is a product of the last few years. The airplane was only a theory little more than fifty years ago. What caused the sudden step-up in the pace of technical progress?

Consider that for thousands of years man moved only as fast as his legs could take him, or a beast of burden could carry him, or a wind could drive him. Not until the nineteenth century and the advent of the steam locomotive and the steamship was there any sharp increase in his speed. In the first quarter of the twentieth century, the development of the automobile and the airplane caused his pace to spurt ahead. Before the century reached its mid-point, he had shot through and well beyond the sound barrier.

What was it that held man back a hundred, or a thousand years ago? All of the raw materials needed for an automobile or airplane existed then. Metals and fuels were in the earth. The atmosphere was subject to the same laws and had the same properties as today. The only thing lacking was a sufficient accumulation of scientific and technical knowledge.

There is a parallel between the rate of increase in scientific knowledge and the rate of increase in speed of travel. The more man knows the faster he travels. Science breeds invention. This dependence of invention on science points toward the laboratory, toward research as the means of replacing our ignorance with knowledge, the ultimate source of development. Great discoveries may seem to come from happy laboratory accidents or wild hunches, but in an ultimate sense they are the products of trained imaginations. The researcher does not stumble vagely about simply hoping to stub his toe on a nugget of knowledge. He proceeds systematically to investigate the fringe areas of what we already know, and his mind takes him from there.

Research and Development— A Three-Fold Activity

The storing of knowledge, the finding of possible uses or applications, and the development of these into products or techniques—these are the steps that lead to revolutionary devices. They are steps which represent the three broad, interwoven activities of research and development: (1) basic research, (2) applied research, and (3) development. The steps are interrelated. They may overlap or seem to take place simultaneously. But they always form the pattern of progress in converting ideas into realities.

In general, basic research supplies the facts, and applied research and development put them to work. Basic research creates fundamental knowledge; applied research surveys that knowledge to find uses for it; and development takes those usable ideas and translates them into machines, materials, or techniques.

To illustrate, Bernouilli, seeking to find an answer to what happens when water flows into a pipe or when one current of air flows into another, did some basic research and arrived at a law governing the flow of fluids. The Wright brothers, applying this basic law to the problem of flight, arrived at some ideas about the flow of air over and around an airfoil, built those ideas into an airframe, and scored a triumph over gravity at Kitty Hawk.

To clarify the nature of the research and development process, let us examine each of its three activities separately, keeping in mind that research and development are interwoven processes and that our division is for discussion purposes only.

BASIC RESEARCH

Basic research seeks knowledge, not mechanical devices. What distinguishes it from applied research is the point of view rather than the method of the researcher. The scientist engaged in basic research is concerned only with reaching an understanding of the subject he is investigating. Practical goals in his investigation might affect the truth of his results. He seeks facts, not applications. When Hertz discovered radio waves, he was not intent upon making a wireless. Nor was Roentgen trying to see through solid objects when he found X-rays.

The scientist's quest need not even continue in the direction in which it started. The consequence of his detours may overshadow in importance his original goal. His only concern is the truth. He must report all the facts and follow them wherever they lead, free from wishful thinking or fixed beliefs that might blind him to their meaning.

APPLIED RESEARCH

Once fundamentals are accumulated, native shrewdness can put them to work. The role of practical investigation or applied research, has already been indicated. It is the systematic survey of basic knowledge to discover possible keys to the development of new techniques or items. There is here a distinct shift in the investigator's point of view. In applied research he sets out to prove that a certain application is feasible. He looks for ideas that he thinks he can use. And he associates closely with scientists and engineers working on actual development.

Doctor Hertz did his work on electromagnetic waves with no specific application in mind. It was basic research. But Marconi, applying Hertz's principles and investigating further, developed a receiver and transmitter and thus opened up the field of radio-telegraphy.

Edison discovered that a wire placed in a vacuum and heated into incandescence gave off electrons, a phenomenon called the Edison Effect. He did nothing with it, however. To him it was simply basic knowledge. Doctor Lee DeForest, applying it, developed the Three Electrode Tube and helped lay the foundation for electronics, so important in military developments.

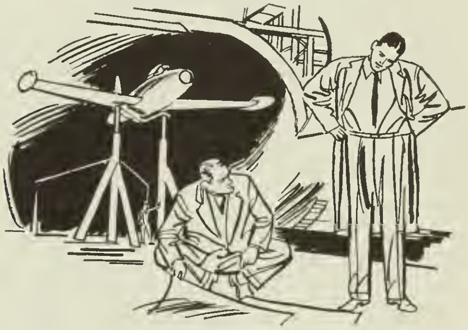
Sooner or later nearly every scientific idea finds its way into the activities of warfare. To speed the adaption of such developments to our military needs, we can screen new ideas which come from basic research. The hydrogen bomb program grew out of just such a screening process.

Development

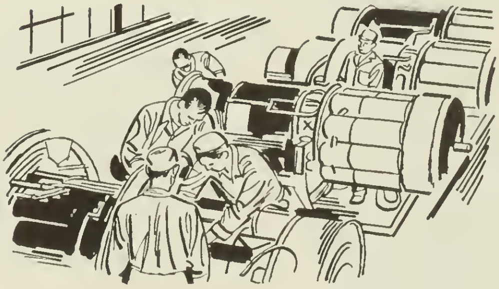
Once a scientist has basic knowledge and has determined how it can be put to work, he is ready to build a model or develop a technique and see if it will do what was intended. At the development stage he is back on firm ground. Moving well away from theory, he takes the first concrete steps toward production. Nothing of course jumps from applied research into actual use. To have an idea is not to have an item. To develop an idea into a working article, the scientist must do some deliberate planning, exercise his ingenuity, and tie together all that is known which can contribute practically to the desired result.

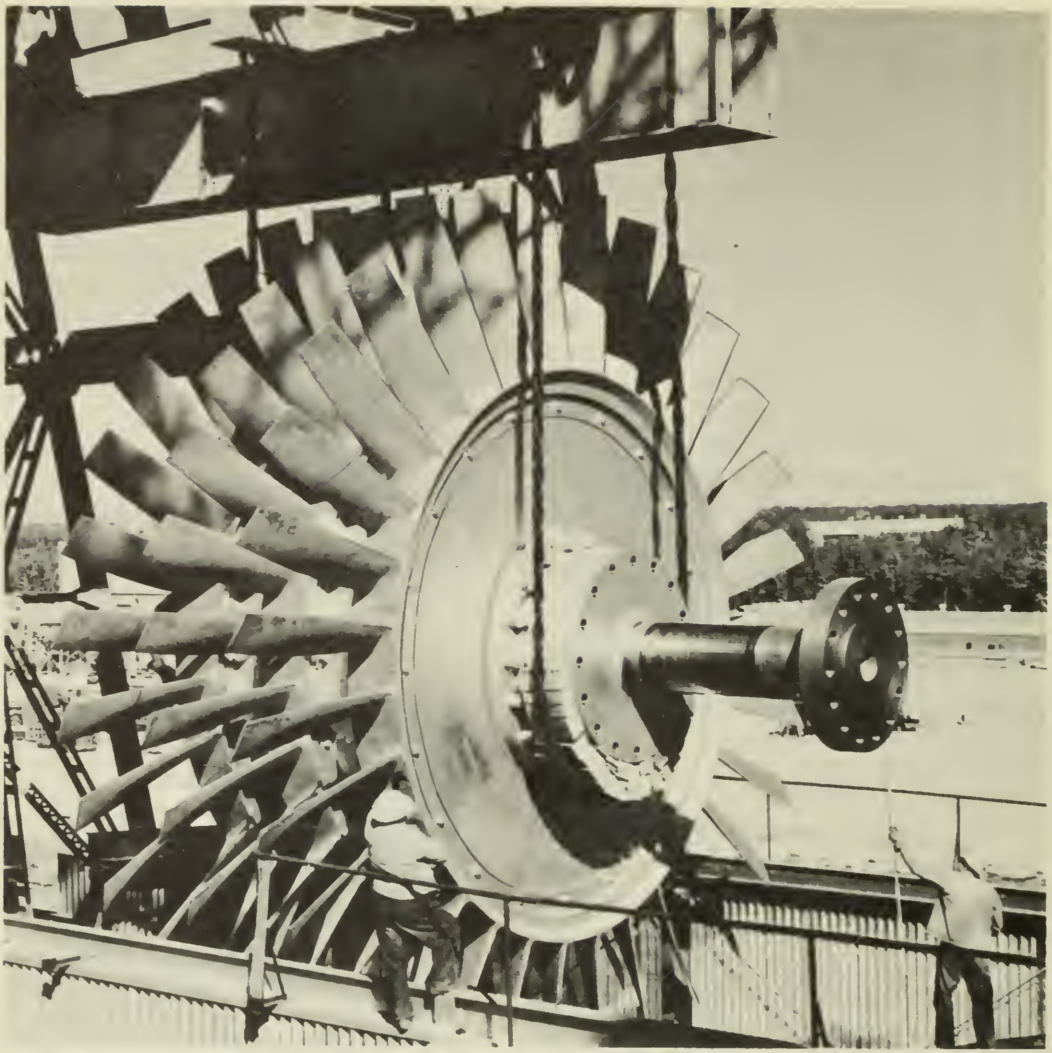
The development process goes through four main stages—the breadboard stage, engineering, production, and testing. Usually the first stage in development is one of experiment, of laying out the parts and fitting them into something that will work. A radio ham would liken it to the *breadboard* stage, in which he strings out radio parts and then connects them to see if they will send and receive. In modern armament development, this first stage may be quite involved because the things being used are far from simple, and the performance standards are severe in the extreme.

The scientists can skip the breadboard stage if the new development is merely an extension or refinement of something already in use, such as a new version of an old aircraft. But the usual transition is through the breadboard stage to the *engineering stage*.



Here the device, weapon, or equipment is refined. Engineers work to improve its performance, to bring it as far toward perfection as they can, and to develop the prototype model—the master model which goes into production.





U. S. Air Force Photo

Giant rotor blades, each weighing 1,200 pounds, developed to push air through the transonic circuit of the propulsion wind tunnel at the Air Force's Arnold Engineering Development Center, Tullahoma, Tennessee. Three rotor stages, each consisting of 97 of these blades, will be positioned in the stator vanes to form the compressor for the transonic circuit. When completed the motor drive system, together with the compressor system, will form the longest rotating mass ever attempted by man (574 feet long or approximately the length of two foot ball fields).

In the *production stage* the prototype model (the pattern) is manufactured. But before production items can start rolling off the assembly line in quantity, engineers must design and make new machinery, tools, dies, or jigs. Radical departures from standard design make retooling a big and costly job. Thus, if designers can get results without making radical changes, they stay as close as possible to familiar, well-tried designs.

The engineering problems of the production line are no small part of the over-all development problem. The assembly line must run smoothly, efficiently, and cheaply. Engineers must eliminate bottlenecks and cut time and cost whenever they can do so without sacrificing essential quality. If possible, they must find substitutes for things that are either expensive or critical and be able to turn them out in sufficient quantities. But even after all apparent obstacles have been overcome, the new item must pass a series of tests before it can go into mass production.

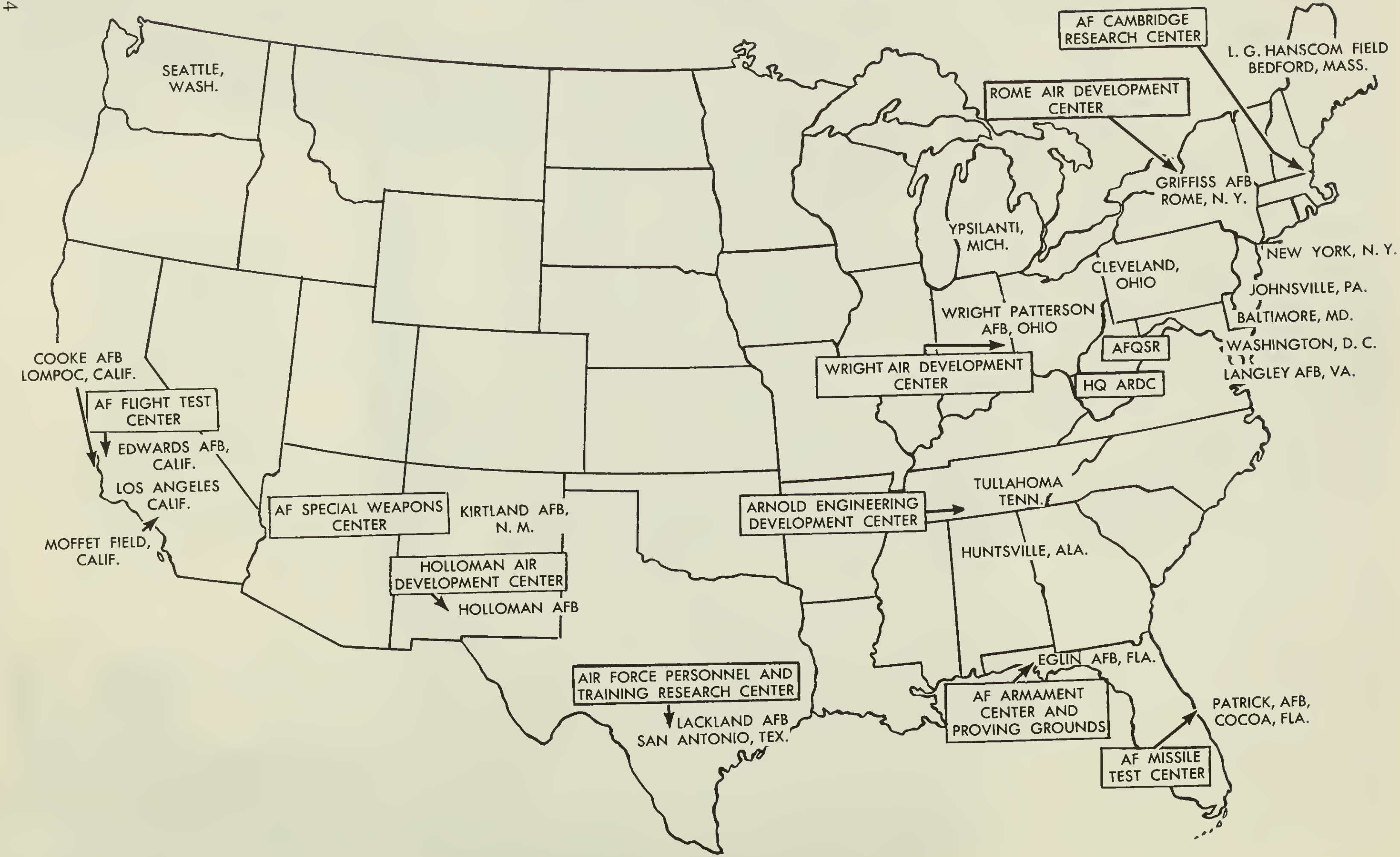
If you have ever built a model plane, the question uppermost in your mind while you were building it probably was, "Will it fly?" Similarly, the big question in development is, "Will it do the job for which it was designed?" Only *testing* will give the answer. Testing newly developed equipment is a major part of the research and development program. Though the manufacturer of military equipment conducts his own tests to satisfy himself that he has met specifications, most of the testing is done by the services.

Engineering, structural, and service tests are normally required for Air Force purposes. In engineering testing, engineers at Wright Air Development Center, Edwards Air Force Base, Patrick Air Force Base, or other Air Research and Development Command centers undertake to find out whether the components or parts will perform adequately under the required conditions.

U. S. Air Force Photo

Air Force test pilots, left to right, Major Charles "Chuck" Yeager and Major Arthur Murray exchanging a hand shake in front of the Bell X–1A supersonic research aircraft. Both are wearing the T–1 high altitude flying suit developed through six years of experiments by the Air Research and Development Command's Aero-Medical Laboratory at Wright Air Development Center, Dayton, Ohio.

Air Research and Development Command Centers.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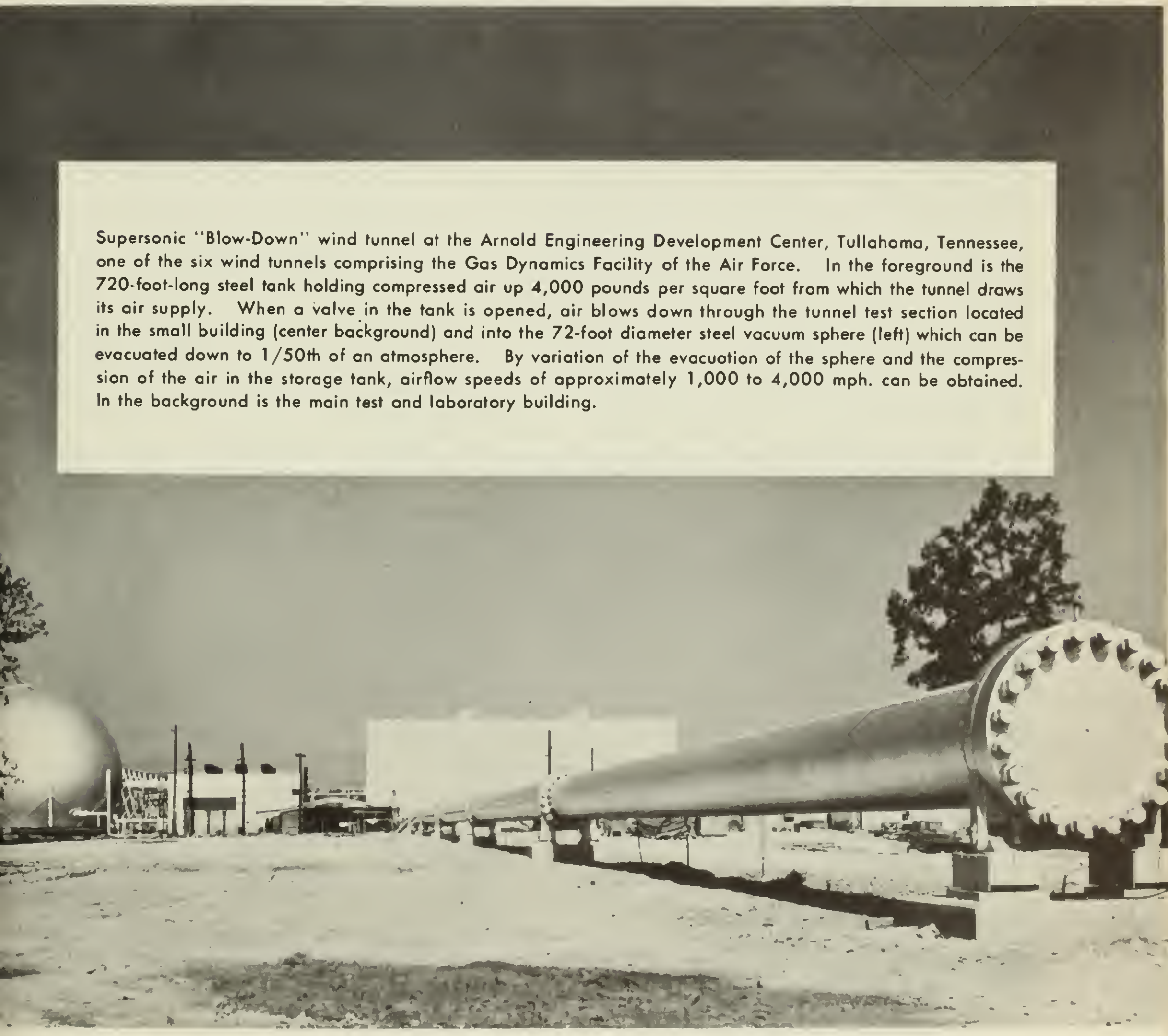
L. G. HANSCOM FIELD BEDFORD, MASS.
ROME AIR DEVELOPMENT CENTER
GRIFFISS AFB ROME, N. Y.
SEATTLE, WASH.
YPSILANTI, MICH.
NEW YORK, N. Y.
CLEVELAND, OHIO
JOHNSVILLE, PA.
BALTIMORE, MD.
WRIGHT PATTERSON AFB, OHIO
AFQSR
WASHINGTON, D. C.
LANGLEY AFB, VA.
WRIGHT AIR DEVELOPMENT CENTER
HQ ARDC
COOKE AFB LOMPOC, CALIF.
AF FLIGHT TEST CENTER
EDWARDS AFB, CALIF.
LOS ANGELES CALIF.
MOFFET FIELD, CALIF.
AF SPECIAL WEAPONS CENTER
KIRTLAND AFB, N. M.
TULLAHOMA TENN.
ARNOLD ENGINEERING DEVELOPMENT CENTER
HUNTSVILLE, ALA.
HOLLOMAN AIR DEVELOPMENT CENTER
HOLLOMAN AFB
EGLIN AFB, FLA.
AIR FORCE PERSONNEL AND TRAINING RESEARCH CENTER
LACKLAND AFB SAN ANTONIO, TEX.
AF ARMAMENT CENTER AND PROVING GROUNDS
PATRICK, AFB, COCOA, FLA.
AF MISSILE TEST CENTER

The structural tests are for safety. They are made to determine the ability of equipment to stand strains and shocks akin to those encountered under extreme operating conditions. Aircraft are tested for structural integrity to the point of destruction as weights are applied at various critical spots.

Service tests are the gauntlet that new developments must run in order to be accepted as combat ready. For a combat pilot what matters most about a new aircraft is its operational suitability. "Will it do the military job it was designed to do?" Service tests, made under simulated combat conditions, answer that question as far as possible without actually putting the equipment through the stresses of war itself. The task of finding out how well equipment can take combat-like conditions usually falls to the Air Proving Ground at Eglin Air Force Base. Service-test reports give the Air Force the evaluations it needs and also indicate whether or not the manufacturer has met specifications. Besides providing evaluations, service tests help in the evaluation of tactics and techniques for new weapons. Test results feed back into development. Engineers must correct any weakness in design and opera-

Courtesy of AIR FORCE MAGAZINE



Supersonic "Blow-Down" wind tunnel at the Arnold Engineering Development Center, Tullahoma, Tennessee, one of the six wind tunnels comprising the Gas Dynamics Facility of the Air Force. In the foreground is the 720-foot-long steel tank holding compressed air up 4,000 pounds per square foot from which the tunnel draws its air supply. When a valve in the tank is opened, air blows down through the tunnel test section located in the small building (center background) and into the 72-foot diameter steel vacuum sphere (left) which can be evacuated down to 1/50th of an atmosphere. By variation of the evacuation of the sphere and the compression of the air in the storage tank, airflow speeds of approximately 1,000 to 4,000 mph. can be obtained. In the background is the main test and laboratory building.

tion that testing reveals. Development is, in fact, a continuing program that runs through production and on during use itself.

Following are some specific subjects being investigated by research and development personnel as part of a constant effort to enable the Air Force to function as effectively as possible anywhere in space, at all speeds, and under all conditions.

The Atmosphere

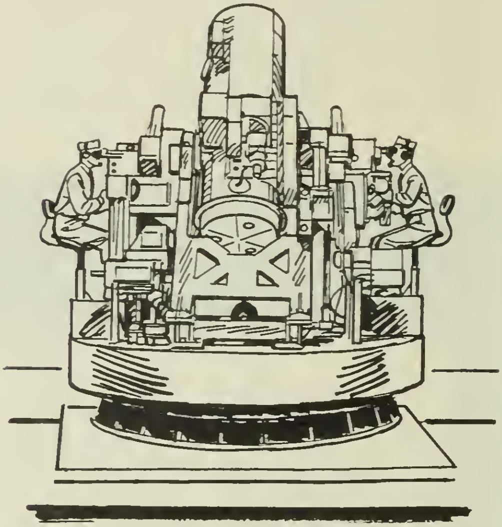
The atmosphere above the altitudes at which we now fly is our last great physical frontier. To go much higher, we must know more about the upper air. At present scientists are studying the regions above us to find out what they are made of, what their characteristics are, and what we must do to fly in them.

As far as we know, the atmosphere that surrounds our earth consists of four layers: the troposphere, seven to ten miles high; the stratosphere, reaching up about 60 miles; the ionosphere, spreading out about 175 or possibly as much as 435 miles; and the exosphere, the fringe layer which may extend 1,500 or even 60,000 miles into space.

Up to a height of about 43 miles the air is about 78 percent nitrogen and 21 percent oxygen, with about one percent of other gases such as carbon dioxide and helium. Dust, bacteria, smoke particles, salt crystals, and other impurities are suspended in the air in quantities ranging from .01 percent to about three percent. Water vapor enters the air from oceans, lakes, rivers, and vegetation-covered land areas. The air's moisture concentration is greatest in the tropics.

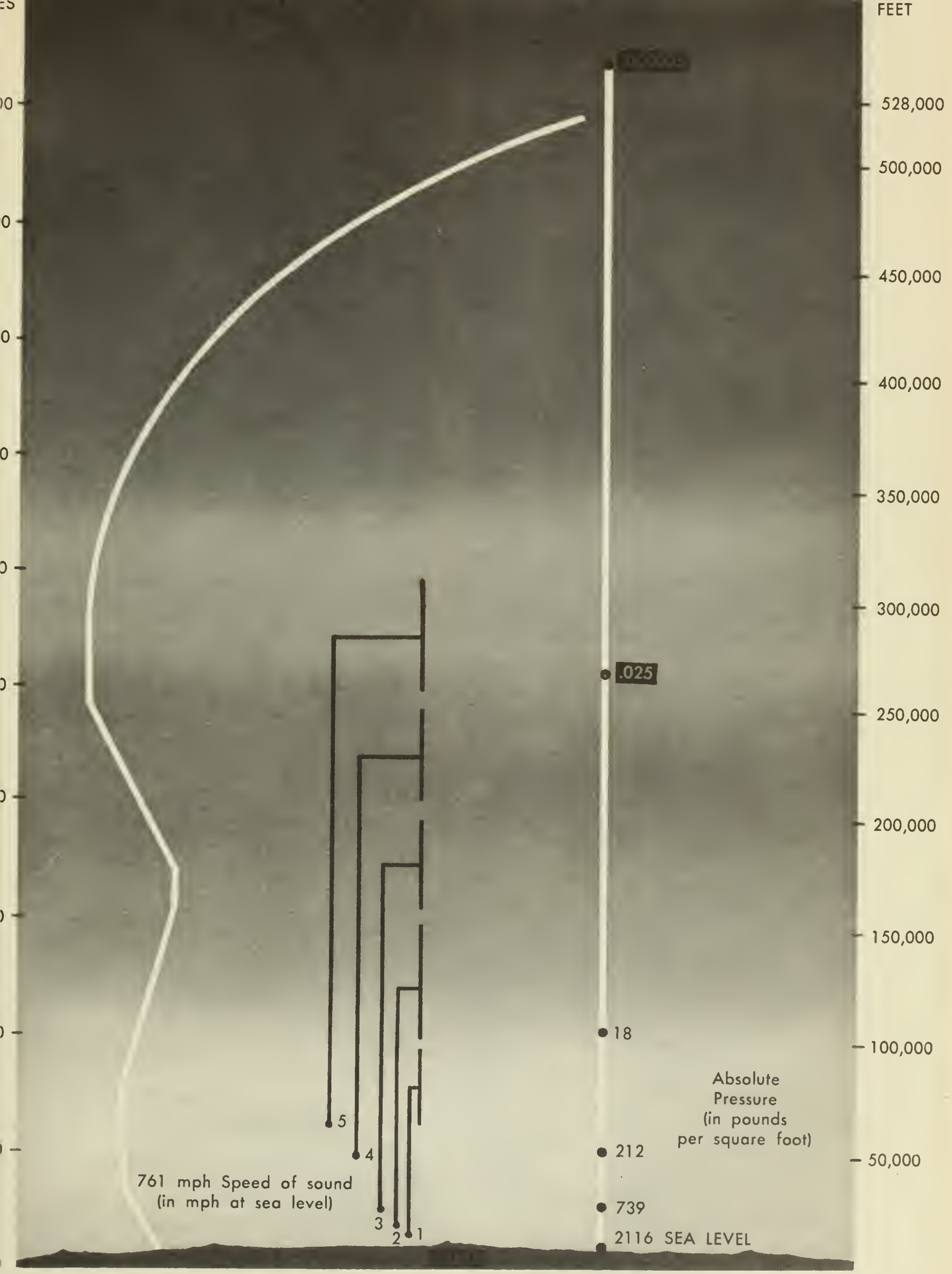
At any point the pressure of the air is equal to the total weight of the air above it. At sea level it is about 14.67 pounds per square inch. The farther you rise above the earth the thinner the air becomes, and the greater the need for oxygen equipment for flyers. Above 40,000 feet the atmospheric pressure is insufficient to force oxygen from the lungs into the blood. Airmen flying that high must use pressure breathing equipment or depend on pressurized cabins.

In the troposphere the temperature customarily drops about 10° F for each 3,000 feet of ascent. Recent investigations have shown that the temperature in the stratosphere varies greatly at different levels. It rises to 1,700° F in the 31 to 38 mile region, falls to 90° F at 50 miles, and then climbs continuously in the ionosphere. The cold stratum in the upper stratosphere may be the result of a concentration of ozone.

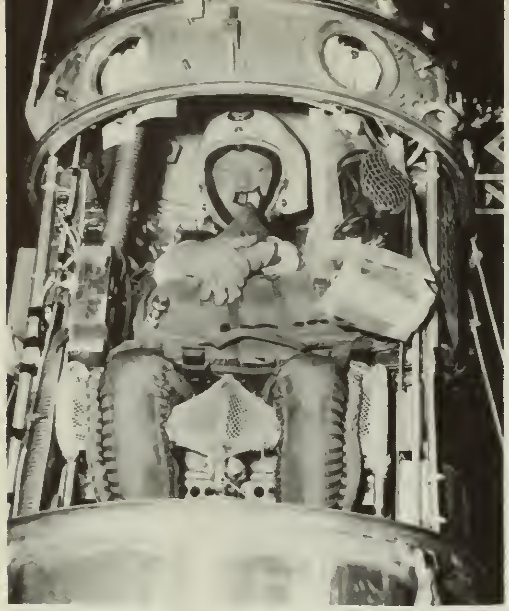


To get our knowledge of the upper air we use two methods: (1) direct investigation—actual sampling and measurement by instruments carried in research vehicles; and (2) indirect investigation—the study of observable atmospheric displays, such as the aurorae, the "Light of the Night Sky," meteors, and cosmic rays, and the behavior of sound, radio, and radar waves at various levels. By applying physical laws to the data we derive from such observations, we can make deductions concerning the nature of the phenomena.

Of particular importance to us is the ionosphere, which acts as a radio wave reflector. The ionosphere is a region containing ionized (electrically charged) particles, whose ionization probably results from the impact of solar radiation on the earth's outer atmosphere. The charged layers reflect the low frequency waves of radio and



Above chart illustrates the dangers as man rises up and out of the Earth's atmosphere. From 15,000–20,000 feet is the highest altitude where atmospheric oxygen will sustain life. At 63,000 feet, blood boils. At 80,000 feet, a sealed cabin with self-contained environment is mandatory. At 130,000 feet, atmospheric shielding of cosmic rays ends. Ninety-nine percent of the atmosphere is located below the 100,000 feet level. Above 75 miles atmospheric shielding against meteors ends. Redrawn with permission, from Air Force Magazine, March 1958.



U. S. Air Force Photo

Captain J. M. Kittinger, Jr., Holloman Air Development Center, New Mexico shown in the gondola of the balloon in which he made his record ascent on June 2, 1957. Captain Kittinger was sealed in the gondola at 1 a. m. and was lifted off the ground at 6:23 a. m. by the two-million cubic-foot capacity balloon. He reached a peak atltitude of 96,000 feet, then a new record for manned balloon craft.

thus make possible communication between widely separated points on the earth's surface. The high frequency waves of radar and television, however, penetrate the layers and are limited to line-of-sight reception. Scientists have gained most of our knowledge of the ionosphere by measuring the absorption and reflection of various electromagnetic waves.

Scientists engaged in upper-air research are studying temperature, pressure, air movements, ionization, cosmic rays, ultra-violet and X-rays from the sun, meteors, the earth's magnetic field, and biological effects of the upper air on living things. Their purpose is twofold: to extend knowledge, and to clear the way for flight through the stratosphere and beyond.

The vehicles upon which the scientists rely for upper-air research are aircraft, balloons, rockets, and satellites. Aircraft are capable of long flights with men and heavy equipment on board, but the altitudes they can reach are relatively low. New plastic balloons—free from expansion while rising, easily launched, and capable of sustained flight—are proving good research vehicles for altitudes around 100,000 feet; and they may yet reach 150,000 feet. More important still are the contributions being made to meteorological investigation by satellites and rockets. The full potential of satellites in this role has not been determined. Experiments have shown, however, that although rockets provide valuable meteorlogical data, they are expensive, do not stay up long, and are likely to destroy their instruments when they come down.

U. S. Air Force Photo

On August 20, 1957 Air Force Scientist, Major David G. Simmons, set a new record for balloonists when he was lifted to approximately 102,000 feet at Crosby, Minnesota. Here the launch crew is waiting for the balloon to align itself vertically above the gondola just prior to launching.

One method developed for recovering rocket-borne instruments without damage has been to eject them by parachute after the planned breakup of the rocket in flight. To get around the need to recover equipment, scientists have turned to radio telemetering, the radio transmission of data from the rockets to the ground.

The efforts of the investigators to determine the effects of the atmospheric conditions at high altitudes on seeds, fungi, and small animals sent aloft in balloons, rockets, and satellites are preliminary to human ascent into the upper air.

Human Engineering

The demands that modern planes make on pilots and crewmen have focused our attention of the problem of man in relation to his machines and led to the work of the human engineers. The human engineers try to fit men to machines and machines to men by furnishing facts about operator abilities and limitations to designers, by providing criteria for the selection of flyers, and by pointing out the techniques which can reduce the strain of speed, altitude, and combat.

The human engineers have brought an organized, scientific approach to operator-machine relationships. Their work has value because the trend toward automatic controls has not necessarily reduced the need for men. Machines extend our abilities and alter our tasks but do not do away with us. They can replace us only in those activities in which our human frailty becomes a limiting factor.

Since a weapon is a man-machine unit, the human engineers work to tailor the components to each other. They help fit men to machines by gathering the data for selection and classification tests. These tests cover physical, mental, and psychological qualifications and special aptitudes, and also make it possible to predict the probable degree of success of individuals as pilots, bombardiers, gunners, etc.

To fit machines to men, the human engineers collect data relating to men as operators of machines, and translate their findings into general principles which designers use for guidance. In particular they are working to establish a body of such principles regarding the size and shape of controls, the direction in which the controls should move for fast and correct pilot response, and the muscular force needed to move them.

Their research activities extend to all the equipment which men use in war and training for war. These investigations provide, for example, the data needed for the preparation of special clothing that can give protection against toxic fuels, extremes of heat and cold, fire, and other hazards. They also supply biological information about man in relation to altitude, speed, and pressure.

The primary goal of human engineering is the collection of basic information about men as operators of machines. We need research of this kind to find out more about average human capacities and limitations, human differences, and the best ways to allow for these differences.

Flight line activities of the Air Force flight surgeon are an important part of his work. This medical officer is discussing the problems of flight and the proper use of personal equipment with the crew members of a Martin B–57.

U. S. Air Force Photo

Aviation Medicine

Aviation medicine takes its program for the future from aircraft and missile advances. The physical and mental hazards of flight that men face today and will face tomorrow are its province. Aviation medicine studies are basic to the development of protective and survival equipment and procedures.

Aero-medical scientists seek to aid vision by improving the design of wind screens and canopies, and by developing better protective goggles and antiglare glasses. In addition, they try to find out what sight signals man can see quickest, and then build these into instrument panels. To counter gravitational forces, they have helped to develop the anti-g-suit, which applies pressure to the body to prevent the pooling of blood in its lower parts. They have also contributed to the design of the ejection seat, a propellant device that can shoot a pilot free of a high-speed aircraft.

High altitudes add to the stresses with which aviation medicine must cope. For night flight above 5,000 feet, and day flight above 10,000 feet, use of oxygen equipment is mandatory. With a close-fitting mask, the demand system of oxygen supply is effective up to about 40,000 feet. Above that, pressure breathing equipment must be used to force the air from the lungs into the blood stream.

The pressurized cabin is the best answer to the high-altitude oxygen problem, but carries with it the danger of explosive decompression. For protection against this, aero-medics have developed an altitude suit—an extra skin which goes on like a coverall and laces to the body. Air tubes run down the arms and legs of the suit. These tubes attach to an oxygen supply and can be inflated automatically or by hand. Tests indicate that the suit may be adequate for altitudes up to 300,000 feet.

In addition to the stresses of high speeds and altitudes, medical scientists are studying the stresses incurred in crashes or ditchings. They are feeding the resulting data to engineers for design purposes and are using it to develop protective procedures and devices.

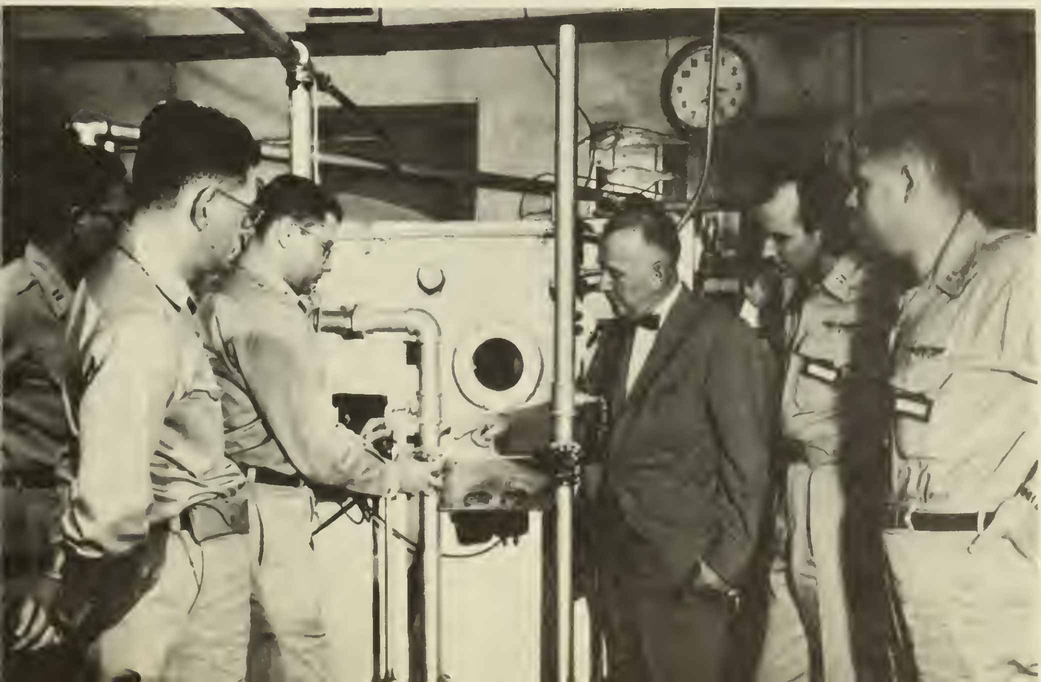
The aero-medics are also constantly studying the pathological and psychological factors of flight and aerial combat. All of their efforts are directed toward maintaining and improving the health, safety, and proficiency of fliers.

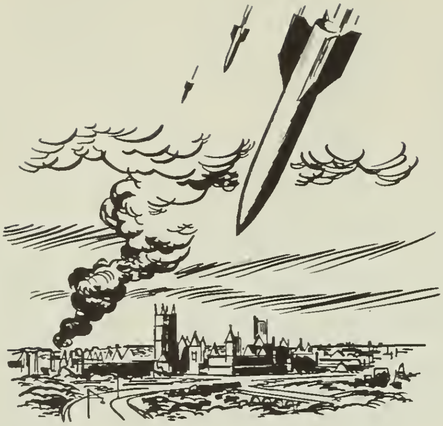
U. S. Air Force Photo

▲ Interior of a low-pressure testing chamber designed to simulate high altitude flight condition. Airman seated is wearing an MC–4 partial pressure suit and is being readied for a simulated ascent. As air pressure in the cabin is reduced, the oxygen assembly will provide oxygen under pressure to the suit and helmet in amounts proportional to the simulated altitude.

Students in the advanced course in Aviation Medicine at the Air Force School of Aviation Medicine receiving instruction in the operation of Air Force's spaceship simulator from Dr. Hubertus Strughold, Director of Space Medicine Research. Cabin is designed to approximate the physiological conditions which airmen will face in space flight. ▼

U. S. Air Force Photo





Missiles

Modern rocket warfare had its beginning with the first launching of the German V–2 against targets in England during 1944. Since then the pace of development has been tremendous, and it is now accelerating almost hour by hour. Guided and ballistic missiles in substantial numbers are already part of the military present, and such mythological names as Thor, Jupiter, Nike, Atlas, and Titan have taken on new meanings as household words.

In spite of newspaper headlines, rocket development the world over is blanketed by secrecy. But about one thing there is open and general agreement. No one doubts that within a few years short-range, intermediate-range, and intercontinental offensive and defensive missiles will dominate human conflict. The key to future military power lies in the attainment of missile superiority, and research and development are therefore being concentrated to an ever growing degree on the new weapons.

Trends in Research and Development

What has been said so far suggests that we are in the throes of building a new Air Force. The discussion has been pointed toward work on the future: research and development to give us new knowledge and new weapons; upper-air research to pave the way for flight through the stratosphere and beyond; human engineering to improve the interworking of men and machines; aero-medical research to solve the physical and mental problems arising from modern flight; and guided missiles to provide a new road to military power.

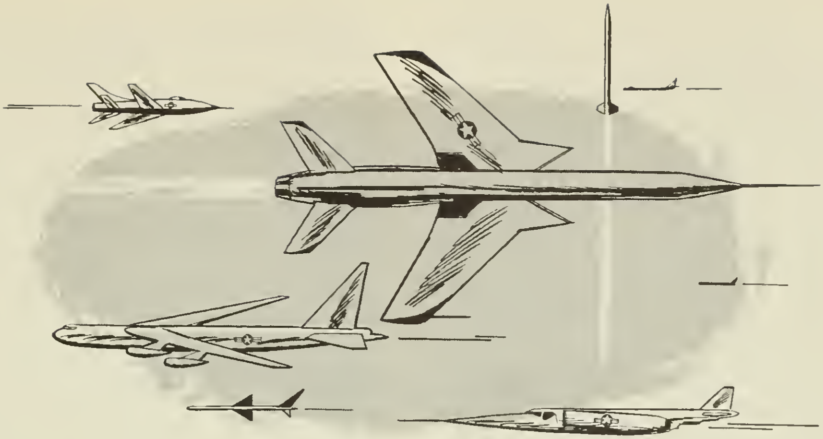
Summary

Our Air Force is always changing. At any one time we are concerned with three Air Forces: (1) The Air Force in-Being—as it exists at the present, (2) the Interim Air Force—the force as it will be during the transition period leading to (3) the Future Air Force. To plan from the present toward the Air Force we will need ten years from now, our planners must read the trends and decide what lines of development and advance offer the greatest promise. In their planning they think in terms of weapon systems—everything needed to get the weapon to the target. By weapon system analysis they can estimate a proposed development's total cost and then come to a conclusion as to whether it offers the best, most economical way of doing a specific job.

The time element is important to all development planning. A new weapon may take from three to five years or more to go through the development and production cycle and be ready for use. The Joint Chiefs of Staff determine our general objectives: What do we need? When will we need it? At Headquarters USAF these objectives are translated into development planning goals, after which the Air Research and Development Command carries out the process of realizing the goals.

For research and development activities we need men, money, and facilities. The money comes largely from the government and from industry, which pour huge amounts of tax funds or earnings into research agencies, and military, university, industrial, and other laboratories. Industry carries most of the burden of development.

For the future we can expect the present lines of advance to continue. The result will be an array of missiles, atomic-powered craft for sea and air, and rockets that reach out into the lonely wastes of space.



MILITARY AIRCRAFT PROCUREMENT

The procurement of U. S. military airraft is the world's biggest business. The nodern combat aircraft is one of civilizaion's great technical triumphs—and one of ts costliest. It is costly because its task is ne of extreme difficulty. Counterbalancng that cost is the fact that the airplane oday is the chief guarantor of national ecurity. Whether it be for reasons of purse r policy, every citizen should have some nderstanding of the enormously complex nd vital activity called *military aircraft prourement*. This section will attempt to fill he need by painting a broad picture of the rocurement function.

United States air power is determined by he Congress. From this single reality all else roceeds. Public control of government pending is the foundation stone of our politcal system. It is simultaneously the open esame to our war-making secrets. Military ircraft procurement means dollars. It has o do with the number of them made availale, the way they are spent, and what the ervices get in return for them. Dollars and vhat is done with them are the key to the tatus of U. S. military air power.

In military aircraft production, as in every ctivity, the armed services are called upon lmost daily to explain where the money oes. The average citizen, rightly conscious f his shrinking pocketbook, tends to point to the high cost of current military aircraft as the culprit. Actually, the culprit is not the airplane itself but rather high altitude, high speed, and radar. These three have driven up costs, compounded complexity, and stretched production items. Lurking in the more immediate foreground is the potential enemy who has aided and abetted these culprits at every turn. He has made it clear that his bombers will be capable of attacking this country at altitudes of 50 to 60 thousand feet or more. He has also made it clear that they will be able to attack at high speed and see their targets regardless of weather. To turn back such a possible assault, this country must have fighters capable of flying higher, flying faster, and seeing better than the enemy's bombers. The nation must also have bombers capable of attacking his cities from still higher altitudes, at higher speeds, and at longer ranges. Of such simple realities are the current combat aircraft design, development, and production problems compounded. Remove the requirements imposed by the threat to us, and the cost of doing business in the air will drop by 90 percent.

It would be nice to be able to place an order at one end of the procurement system, forget about it, and then pick up the finished product at the other end. Aircraft production takes far more than that. In recent years the whole production system has had to be thoroughly overhauled and greatly expanded. Just as the nature of aircraft has changed, so too has the nature of the equipment and methods used in its production. High strength alloys require tougher drills, bigger presses, and stronger shears. Since the load on the tapered aircraft wing lessens toward its tip, so too does the wing skin thickness. The new wing needs either machine or roll taper skin plating. These thin tapered skins require both new tools and entirely new plants for their production.

The aircraft buying function involves the talents and efforts of tens of thousands of experts in industry and in government. The buying function simultaneously creates the selling function, and still more tens of thousands of salesmen are part of the procurement team. In the background of the aviation procurement effort, however, is the real buyer of everything that goes aloft in the airplane, the engineer. Until a product is made a part of the aircraft design, until it is specified on a drawing, and until it has been incorporated in an operating system within the airplane, it is only a conversation piece between the buyer and the salesman. Problems of price, delivery date, supplier selection, shipping, insurance, guarantees, receiving, inspection, and warranty provisions—all these things and a host of others are vital purchasing matters for industry and the government. But none of them is fundamental. What counts is the decision to use an item. That decision is the sole responsibility of the engineer, the real buyer of the aircraft.

The task of Air Force procurement is vested in the Air Materiel Command (AMC). Before 1951 this command was also responsible for all Air Force research and development. In May, 1951, however, there came a basic change. It was designed to enable AMC to concentrate on improving the quality of materiel, and also to permit increased emphasis on the research and development process. Under the reorganization plan AMC's research and development function went to the new Air Research and Development Command.

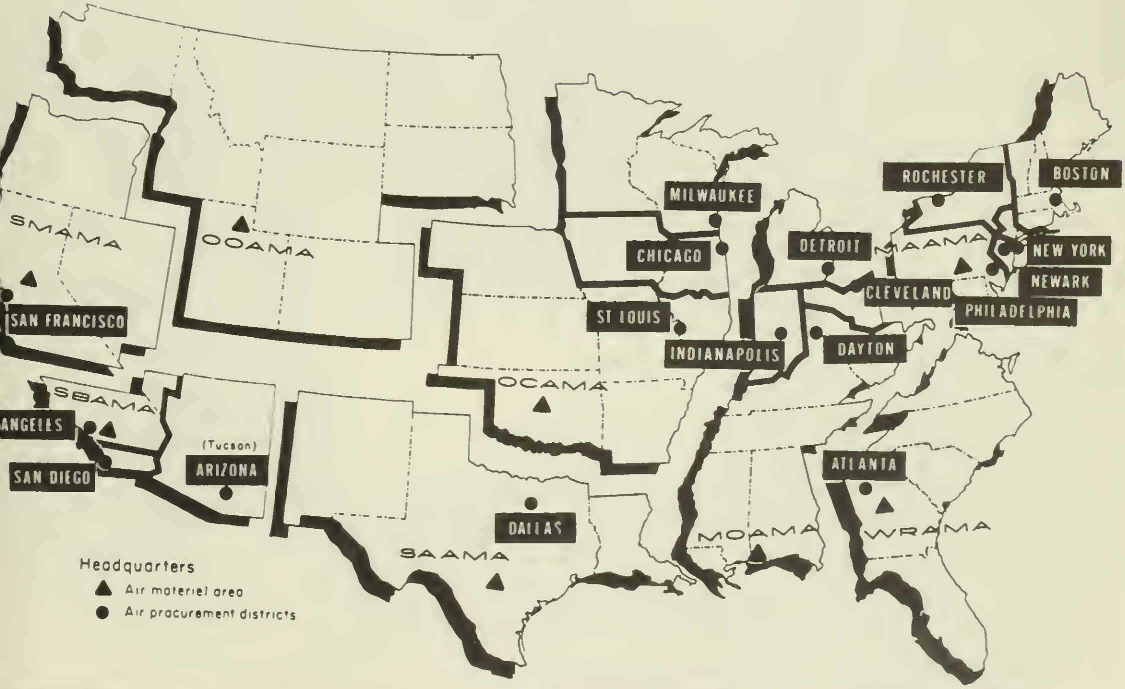
It has been said that the heart of the U. S. Air Force is the Air Materiel Command, with headquarters at Dayton, Ohio. It furnishes logistic support for the USAF and for all allied air forces using United States aircraft. Because of the size of its job, AMC spends more money than any other single organization in the nation. To understand AMC it is necessary to understand what it does and how important it is to all industry. It has become so big a business that its activities affect the economy of the entire nation. Because the Air Force receives the largest appropriation of any of the military services, and because AMC spends the money, the command inevitably has a far-reaching influence. It can stunt or feed inflation, raise taxes or hold them to current levels, and give the nation an effective defense or render it helpless.

Few people outside the Air Force have a very clear picture of how the requirements for new aviation equipment are established and the winding trail which they follow from the originators to the Air Materiel Command, which does the actual purchasing. To get this picture and understand its complexities, it helps to have some grasp of the weapon system plan which the Air Force now uses. Briefly, this is a requirement planning concept which provides for the coordination of all the items which go to make up a complete aircraft or major piece of ground or airborne equipment. Into these weapon system plans are fitted the requirements for tomorrow's combat and supporting equipment that stem from the user organizations of the Air Force. Pilots and ground crews, the operational personnel in the field, are the first to see the inadequacies of today's equipment and to want improvements. Their observations funnel into USAF Headquarters in Washington to be translated into new requirements.

Most of the principal U. S. aircraft manufacturers keep a staff of technical representatives in the field with their equipment. Their task is not only to trouble-shoot but also to observe new requirement trends so that the manufacturers can keep up with operational thinking about tomorrow's equipment. In many cases the industry is in a position to suggest future requirements as a result of its follow-ups in the field.

The Procurement Division of AMC does the actual buying for the Air Force. In the Procurement Division can be found a number of subordinate organizations, each responsible for purchasing a certain group or groups of Air Force equipment. In order that the Air Force may be physically close to the actual work being performed by industry, contract administration has been delegated to the commanders of the six air procurement districts, each of which is an organization within the Air Materiel Command reporting directly to the Commander, AMC. These procurement districts in turn have jurisdiction over more than twenty regional offices located in industrial centers of the United States, and also over a number of Air Force plant representatives located at the larger airplane and related manufacturing plants.

Taking a cue from private industry, AMC has decentralized its program. There has been a farming out of more than 200 classes of Air Force property, above five billion dollars of funds, and 350 tons of records. The program places with AMC depots what is, in some cases, complete responsibility for commodities they handle— including procurement, storage, shipping, and maintenance. It puts all the persons concerned with one item in one place. This makes life easier for those doing business with the Air Force, and saves the government millions of dollars in time and telephone calls alone. Decentralization also leaves AMC headquarters free to do a better planning and management job for an organization that towers over any buyer and supplier in the nation.



–MIDDLETOWN
–MOBILE

OCAMA–OKLAHOMA CITY
OOAMA–OGDEN

SAAMA–SAN ANTONIO
SBAMA–SAN BERNARDINO

SMAMA–SACRAMENTO
WRAMA–WARNER ROBINS

Air Materiel Areas and Air Procurement Districts.

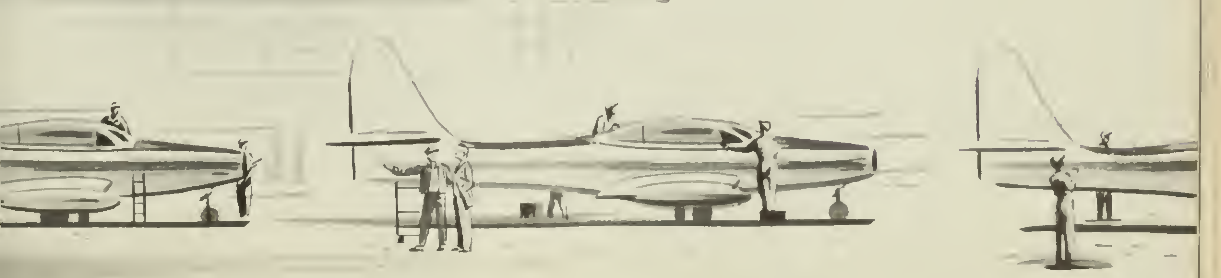
PART 1

CHAPTER 4

The Aircraft Industry

ORIGIN AND DEVELOPMENT [1]

The modern aircraft industry may be said to have had its beginning in a Dayton, Ohio, bicycle shop, where the Wright brothers designed and partially built their first heavier-than-air machine. The achievement of powered, sustained, and controlled flight, however, was too significant for production of the new vehicle to remain in the narrow confines of a bicycle shop, or, for that matter, any single shop. Within the United States the Wright brothers, Alexander Graham Bell, Glenn H. Curtiss, and Glenn L. Martin laid the foundations of the American aircraft industry. From a modest beginning in 1909 of three companies employing a handful of people, the United States aircraft industry had grown, by the Golden Anniversary of Flight in 1953, to be the second largest manufacturing enterprise in the land. By that year the aircraft manufacturing industry alone, not to mention a host of allied industries on



Wright Brothers bicycle shop at Dayton, Ohio, birthplace of American aircraft industry. U. S. Air Fo

which it depends for a large share of the equipment which goes into a modern aircraft, employed 750,000 people. The best index of the industry's importance however is its product—military and civil airplanes and missiles. Upon the quality and number of planes and rockets designed and produced, America depends today for its survival.

Military Impact on Aircraft Development

As now, so in the early years of the 20th century, governments spurred research on heavier-than-air machines because of their military usefulness. The first sale by the Wright brothers to the United States Army was in 1908. The American Government nevertheless lagged far behind France, Germany, and Britain—the great powers which dominated the world politics of that era. For example, while the Federal Government spent $500,000 to foster the infant aircraft industry, the German Government expended over 50 times that sum during the same period (1908–1913). France, of course, led all the world in aeronautical activity, development, and production.

There the aircraft industry was led by such pioneers in aviation as Ernest Archdeacon, Charles and Gabriel Voisin, Louis Bleriot, Henry Farman, and Charles and Edward Nieuport. It received ready backing from both government and private capital, unlike its American counterpart.[2] The

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[1] Material in this section is derived primarily from "A History of the United States Air Force—1907–57", *Air Force*, Vol. 40 (Aug 57).

[2] American aircraft producers found it difficult to extract large sums of money from private capital. The patent infringement claims, initiated by the Wright brothers, and the seemingly endless litigation over patent rights made many influential and wealthy well-wishers wary of investing their money in aircraft production plants.

U. S. Air Force Photo

British were slower than the French to become convinced of the practicability of heavier-than-air flight. Nevertheless, almost from the beginning of powered flight, a few men of vision saw the importance of the invention and recognized its war-time threat to Great Britain's island position.[3]

In the United States the outbreak of war in 1914 saw 16 aircraft producers of sufficient importance to be included in the *Census of Manufacturers.*

The U. S. Aircraft Industry in the First World War

Glenn H. Curtiss, pioneer aviation enthusiast and later a leading aircraft manufacturer, in front of one of his early planes. He founded the Curtiss Company, which in 1929 combined with the Wright Aeronautical to become the Curtiss-Wright Corporation.

When the United States entered the war in 1917, the Air Service, as the military air force was then called, had less than 250 aircraft. Not one was suitable for combat service. In 1916 nine aircraft companies had delivered to the Army only 64 out of 336 aircraft ordered. Furthermore, the performance of these airplanes compared unfavorably with that of European models. Yet, enchanted by the vision of a vast American air armada which would make our might immediately felt in the theater of war, Congress passed in 15 days an act appropriating $640 million for aeronautics. This amount was the largest sum appropriated for a single purpose up to that time.

Yet years of neglect could not be speedily compensated for by dollars alone. From the first Wright airplane in 1903 through 1916,

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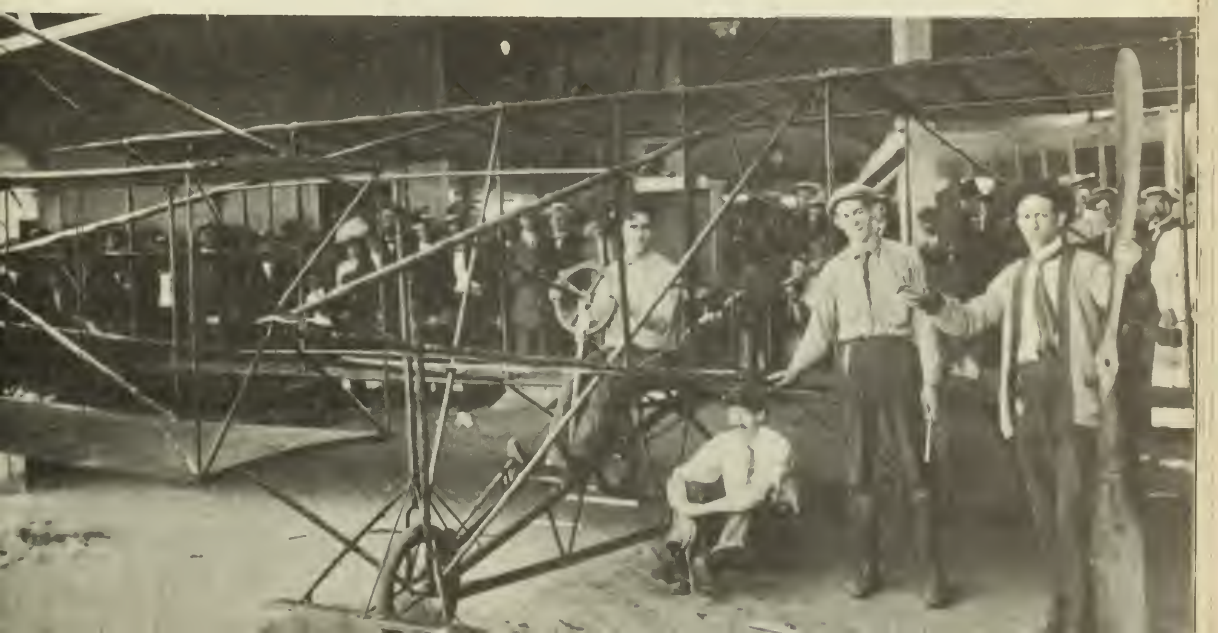
[3] Lord Montague in Parliament and Lord Northcliffe, through his newspaper, the *Daily Mail,* sought to warn the public of the danger. Lord Northcliffe offered sizeable awards, such as 1,000 (British) pounds for the first flight across the channel, and 10,000 (British) pounds for the first flight between London and Manchester, as a means toward subsidizing the British aircraft industry. Although no plane of British design or manufacture won either of these two prizes, these awards and others spurred an interest in aircraft production in Great Britain.

Plane which Glenn Curtiss flew from Albany to New York on May 20, 1910. For the flight, floats were used in place of the hydrosurfaces shown in the photograph.

U. S. Air Force Photo



the American aircraft industry had produced less than 1,000 military and civil airplanes. In the summer of 1917, the War Department, disregarding the advice of the National Advisory Council on Aeronautics, called for the production of 22,000 aircraft in one year, the equivalent of 17,600 more aircraft in spare parts, and 44,000 engines. These unwarranted hopes were soon dashed as the production program fell far behind schedule.

The greatest problem proved to be the production of combat planes fit for use in Europe. As an Air Force historian, Alfred Goldberg, observed, "None had ever been produced in this country, and no one had the technical knowledge to do it quickly. There were not even any designs for such planes. The greatest deficiency was in engines." The United States in 1917 did not produce a single power plant that combined the qualities of light weight and high power required for combat aircraft.

Consequently the United States had to turn to its Allies for planes to equip its units at the front and for the technical knowledge that would enable it to produce combat planes for itself. Without such assistance, the U. S. Air Service would not have been able to make the gallant, albeit brief, combat record that it did. Nine types of Allied planes were bought for use by U. S. air units.

U. S. Air Force Ph

World War I DeHaviland DH–4 reconnaissance bomber.

U. S. Air Force

British Handley Page bomber. Though placed in production by American firms during World War I, only a few of these planes were produced by the end of the war.

After much discussion the Americans decided to produce the de Havilland 4 (DH–4), a two-place reconnaissance bomber of English design, in the United States. Though U. S. companies later placed the British Handley-Page bomber and the Italian Caproni bomber in production, only the DH–4 was produced in quantity. Manufacture of other European models was contemplated and even undertaken, but none actually reached the production stage prior to the Armistice. The only American-designed combat plane developed during the war was the two-engined Martin bomber, built around the American Liberty engine.

Although this plane failed to get beyond the developmental stage in 1918, it became the standard bomber of the Air Service in the early 1920's.

DH–4 production rose from a mere 15 in April 1918 to 1,097 in October. Well over 3,000 DH–4's were manufactured before the Armistice. To these may be added about

Italian designed Caproni night bomber built in the United States during World War I. U. S. Air Force

,800 training planes—mostly the famous
–N's or Jennies—and a few hundred com-
at-type planes other than the DH–4. Al-
iost all aircraft in the latter category were
xperimental or test models. Thus over
1,000 planes were produced in all.

American aircraft production nevertheless
'as a failure, if judged by original goals and
romises. But, when compared with air-
raft production of other belligerents, it was
substantial achievement. During 19
ionths of war, the United States produced
0 percent more aircraft than did Great
ritain during her first 31 months of war—
nd Great Britain was the largest Allied
roducer.

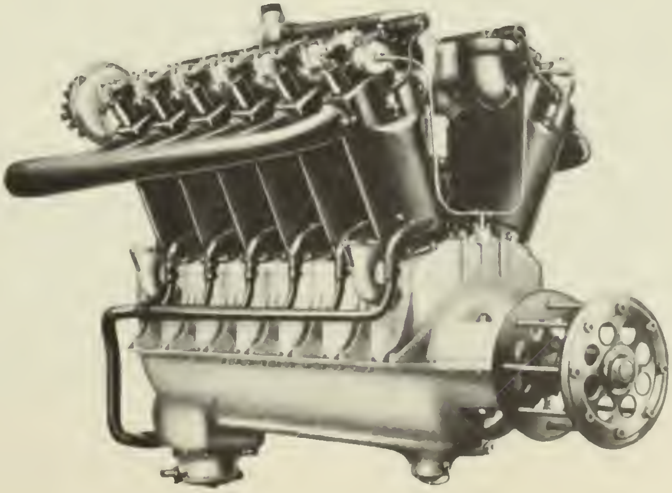
Considering the initial lack of a good mili-
ary aircraft power plant, it is a paradox that
ie outstanding contribution of the United
tates to aeronautical development during
ie war was the Liberty engine. Although
ie United States employed nine types of
oreign aircraft and even began to produce
ome Allied engines, the Allied Powers soon
ooked to the American Liberty engine as
ie type preferred in their own planes.
gainst 44,000 ordered, engine makers
irned out 32,000 units. Almost one-half
f these were Liberty engines.

Inter-War Fluctuations

Only a few days before the Armistice, military orders for 13,000 aircraft and 20,000 engines were cancelled. Ninety percent of the war-swollen aircraft industry vanished from the industrial scene by 1920, and the survivors saw only a bleak existence immediately ahead. The disposal of surplus airplanes and equipment further depressed the civilian market. Annual production capacity shrank from approximately 21,000 airplanes at the end of the war to an estimated 500 to 1,200 in 1925.

In the mid-twenties the Morrow Board was appointed by President Coolidge to study national aviation policy. It placed major stress on the civil aspect of aviation, as we shall see in the airlines chapter. Nevertheless, its recommendations led to the passage of the Five Year Program Acts of 1926, under which the Army and Navy received increased appropriations for aircraft. In the next year Charles A. Lindbergh's sensational non-stop flight from New York to Paris touched off a wave of aeronautical enthusiasm. New aircraft plants were formed with the sudden influx of capital; established aircraft and airline firms merged to increase their operating efficiency; and the names of

Drawing of the American Liberty engine. It had 12 cylinders and developed 400 horse power.



Colonel Charles A. Lindbergh.

Lindbergh's non-stop flight from New York to Paris created great enthusiasm for aeronautics and led to great expansion of the American aircraft industry.

new holding companies appeared across the nation. In the next two years the aircraft industry expanded rapidly and hiked the number of people on its payroll to 100,000.[4]

The history of the decade after 1929 may be summarized in three words: depression, rearmament, and technological advance. With the onslaught of the Great Depression, annual U. S. production dropped from over 6,000 aircraft in 1929 to hardly more than 1,000 in 1933. Congress also stopped appropriations for completion of 1,800 military aircraft, which had been authorized under the five year procurement plan. However, the U. S. aircraft industry began to revive, even before the clouds of war darkened over Europe. As we shall see in the next chapter, the industry's development of economically self-sustaining airliners in the early 1930's contributed significantly to the rapid growth of airline passenger traffic; this in turn meant more airline business for the aircraft producers.

Though growth of the aircraft industry in the United States was steady after 1932, it was accelerated around 1935 as general rearmament began throughout the world. Military aircraft orders increased, and foreign markets for American commercial airplanes expanded at the same time. Even though the Army Air Corps had only 300 combat-ready aircraft in 1936 and the United States ranked but sixth among world powers in combat aircraft strength in 1937, the aircraft industry as a whole was considered by U. S. authorities to be at least 18 months ahead of any foreign competitor in plant facilities.

Impact of the Second World War

The rate of industrial expansion increased still further in 1938 and 1939 as a result of French and British orders for United States military aircraft. In January 1939, President Roosevelt asked Congress to provide the Army Air Corps with 6,000 aircraft at an estimated cost of $4 million. At that time there were roughly 100 industries associated with the manufacture of aircraft and their combined monthly production capacity amounted to 500 planes. In relation to other American industries, aircraft manufacturing ranked 44th in value of product.

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[4] Aircraft Industries Association, *The Aircraft Industry, 1903–1953* [mimeo.] (Washington: n. d.), p. 3.

In May 1940, as France reeled under the blows of Nazi dive bombers and tanks, President Roosevelt called on the aircraft industry to gear itself to produce at least 50,000 airplanes a year. This was more than the industry had made in its entire history. In 1944 American aircraft industries produced almost double this number. During the Second World War they manufactured approximately 300,000 aircraft for the armed forces. Eleven leading companies produced over three-quarters of this total. Aircraft manufacturing had now risen from a relatively minor position among United States industries to become the largest in terms of annual value of product.

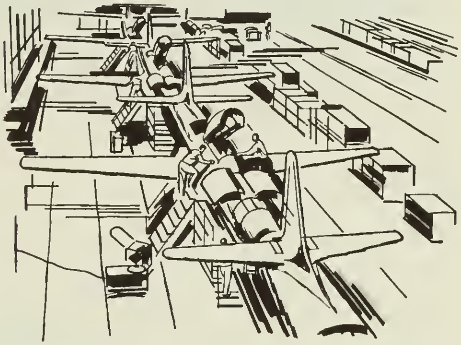
Industrial Mobilization Planning by Air Force and Industry

After the war was over, the Air Force began to draw up industrial mobilization plans to speed the process of aircraft plant conversion to military production in the event of future emergencies. Profiting from their prewar and wartime experience, Air Force officers contacted aircraft manufacturers and requested advice on ways and means of reducing the time element between the start of a future mobilization effort and peak production. Leaders and plant managers indicated the materials, machinery, men, and plant facilities that would be needed under the above conditions. They based their plans for volume emergency production on the maintenance of a stable aircraft industry. Upon this base, large scale military production was to be achieved by changing manufacturing methods, modernizing machinery, and buying new tools. Technological advances made during World War II were fitted into their plans. Later, under the provisions of the National Reserve Act of 1948, a military reserve of important government-owned facilities was established; in addition, other plants and facilities built at government expense were sold or leased with the understanding that they could be used by the Air Force in the event of war. In regard to the latter category, the current owners were required to keep the plant on a "standby" alert for reconversion to wartime production on four months notice. Furthermore, the Department of Defense in 1947–48 began allotting key industrial plants among the three services. On the basis of its mobilization plan, the Air Force began compiling tentative production schedules with the plant managers of the industries within its jurisdiction. Under this system, the aircraft industry learned what it was to produce and the Air Force found out what the industry required in the way of facilities to meet its goals.

The wisdom of these procedures was realized during the Korean War. One year after the beginning of hostilities, 92 percent of the standby facilities were in operation on a wartime basis for the Air Force. In addition to the standby plants, the Air Force was required to build new facilities and enlarge existing ones. Congress assisted by appropriating $2.2 billion for purchases of land, buildings, and machine tools by manufacturers who were financially unable to bear this expense. The service utilized $2 billion of this amount and kept the remaining funds for additional plant expansion. The government, in addition, provided incentives to manufacturers to employ their own capital in the expansion process.

After the Korean War, however, the Air Force found that it needed to retain in current production only those plants which could lend themselves to the development of new types of weapons and equipment. Aircraft plants no longer essential to military production were allowed to convert to civilian manufacturing; others were put on a standby notice. Government-owned plants not required for mobilization were sold outright. The aircraft plants retained by the Air Force were those which were especially adapted for development activities and capable of rapid expansion in production.

In January 1954 the Air Force streamlined the production allocation program to fit the needs of the jetomic age. It concentrated on allocating the production of critical items and components that were likely to become bottlenecks in time of mobilization. Items which could be readily purchased on the open market or easily manufactured were eliminated. Precautions were also taken to insure that more than one source of supply existed for each item and that the suppliers were geographically dispersed. In case of a general war, American industry planned to deliver all critical equipment within the first 60 to 90 days after hostilities broke out.



Production After the Second World War

The years immediately following the war nevertheless saw military orders for aircraft drastically curtailed. Aircraft producers faced a crisis situation. This development in turn undermined the entire mobilization plan of the Air Force. Simultaneously, many contractors converted to the production of consumer goods and showed little enthusiasm for returning to military production.

The experience of North American Aviation, Inc., illustrates the plight of aircraft companies after the war. Immediately prior to the Japanese surrender in August 1945, North American had unfilled orders on its books for more than 8,000 airplanes. Within 24 hours 90 percent of these orders were cancelled. Three months later the company had unfilled orders for only 24 airplanes. With less than 5,000 people on the payroll in 1946, employment at North American fell to a postwar low.[5]

The cancellation of government orders for military aircraft at the end of World War II left aircraft industries in a precarious position. Manufacturers delivered approximately 1,500 military airplanes to the government in 1946 as contrasted to 1,800 in 1936, the last normal prewar year, and 96,000 in 1944, the peak wartime year.[6] In 1948, Congress granted almost $2 billion to the Air Force to meet the needs of the first year of a new five-year aircraft purchasing program. It was set up as a result of reports by the Congressional Aviation Policy Board and the President's Air Policy Commission.

Hardly had the program begun when the Air Force was compelled to halt its spending in December 1948, owing to the prospect of reduced funds in the future. It had to cut back its planned strength from 70 to 48 groups.

With the outbreak of the Korean War in June 1950, the Air Force readjusted its goals upward to 90 wings.[7] One year later, it planned to spend approximately $6.86 billion of its new fiscal year 1952 funds

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[5] United States, House of Representatives, 84th Congress, Second Session, *Aircraft Production Costs and Profits,* Hearings before the subcommittee for Special Investigations of the Committee on Armed services (Washington: 1956), p. 1389.

[6] Aircraft Industries Association, *op. cit.,* pp. 5–6.

[7] For the purposes of our discussion, the terms *group* and *wing* may be used interchangeably.

PPROPRIATIONS AND EXPENDITURES FOR MILITARY AVIATION, 1944–57

[Millions of dollars]

Fiscal year	U. S. Air Force	
	Total cash appropriations	Expenditures
944	23,656.0	13,087.7
945	1,610.7	11,357.4
946	.5	2,519.4
947	1,200.0	854.3
948	[a] 608.1 829.8	1,199.1
949	939.8	1,830.7
950	4,139.4	3,669.1
951	15,791.1	6,549.4
952	22,979.0	12,594.9
953	22,081.7	15,267.8
954	11,410.5	15,539.6
955	11,637.1	15,536.8
956E	15,490.1	15,988.0
957E	15,430.0	16,545.0

N.A.—Not available.

E—Estimate.

[a] FY 1949 Construction of Aircraft and Related rocurement appropriation enacted in FY 1948.

Sources: 4, 8, 49, 82.

o purchase 5,600 airplanes. In late 1951, owever, the National Security Council deided that 143 wings were required to proide the air power necessary to assure adeuate national defense; this force was to be uilt by 1955. To meet these goals the Air Force earmarked $7.4 billion of its fiscal ear 1953 funds for the purchase of over ,000 aircraft.

Although plans for the size of the air arm fluctuated during the early 'fifties, the aircraft industry was able to increase production five-fold. In late 1952 these manufacturers were producing 650 planes a month as compared to 130 per month two years earlier. During the first half of 1953, more than 4,000 airplanes were delivered.

The first prototype of the F–84F fighter-bomber was successfully flown in June 1950, just prior to the outbreak of hostilities. Less than a month later, the Air Force awarded the initial contract to Republic Aviation Corporation. Twenty-nine months later, in November 1952, the company delivered the first Thunderjet to the Air Force.

The end of open conflict in Korea saw planned Air Force strength drop from 143 wings to 120, and then rise to 137. As a result, the service cut its orders for trainers, transports, and supporting aircraft. With the stretchout of aircraft production schedules, output remained stable during the latter part of 1954, declined in 1955, and leveled off in 1956.

The introduction of guided missiles called for the expenditure of funds at the expense of airframes. Individual companies soon felt the effects of this decline in aircraft deliveries. During the fiscal year 1956[8] the Air Force released more than $8 billion for procurement, one-fifth of which was spent for missiles.

With the great advances in technology since World War II, air vehicles have become more difficult to build. Reciprocating

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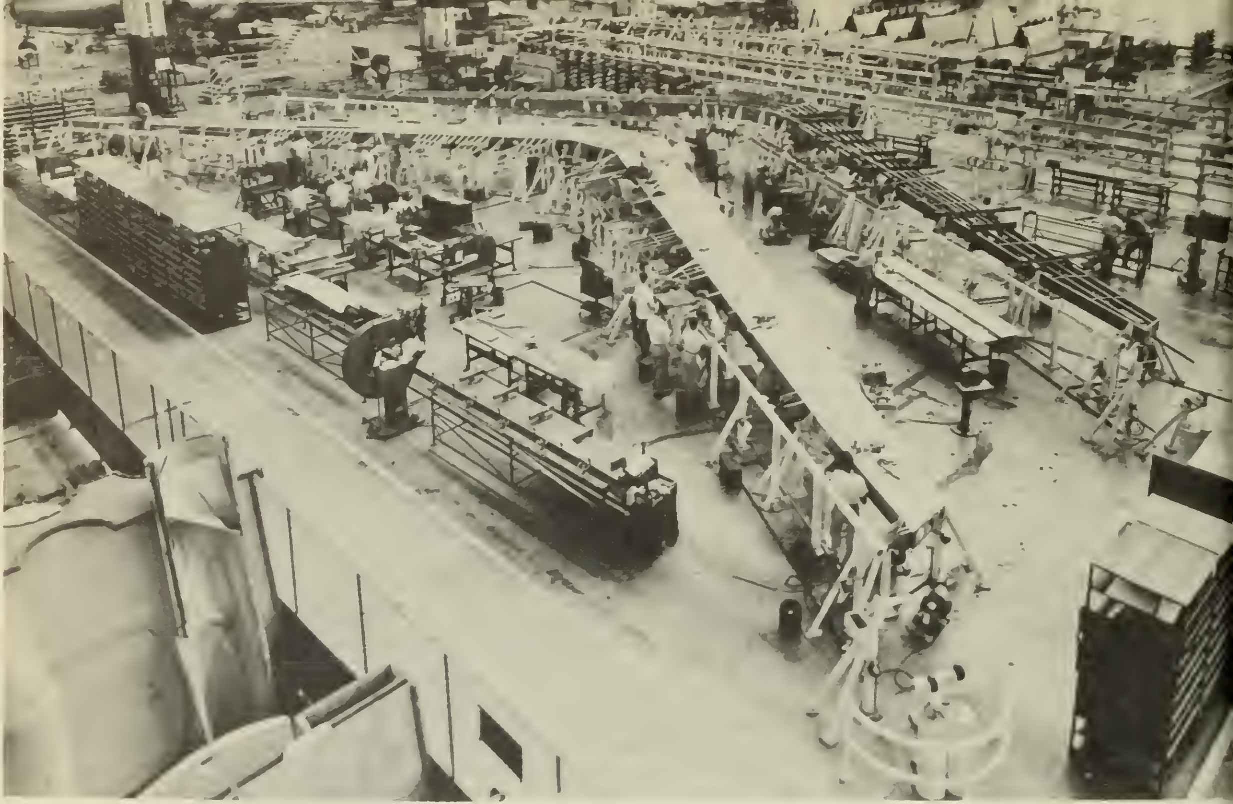
[8] 1 July 1955–30 June 1956.

Republic F–84 Thunderjet fighter-bomber.



B–47 assembly line operations at Boeing Aircraft Plant, Wichita, Kansas

U. S. Air Force

engines and airframes of light sheet metal have been replaced in large part by jet engines and airframes of heavy sheet metal. These major strides in aviation development have brought about much higher aircraft performance. The accompanying complexity of manufacturing, however, has ruled out large-scale application of mass production techniques and attendant savings in time and money. For example, in constructing a B–47 jet bomber, each of the 6,000 bolt holes in the wing has to be accurate within one- to two-thousandths of an inch—less than the thickness of a human hair. In order to insure sufficient strength in supersonic flight, the thin wings of the Stratojet have to be virtually hand-carved from solid metal.

The production difficulties encountered by aircraft manufacturers were multiplied during the Korean War. Scheduled delivery dates were frequently not met, and even those schedules which had been stretched out did not materialize as anticipated. Yet to understand the problems of production, it is necessary to point out that only limited mobilization was in effect at that time. Many industries continued to produce civilian goods, and in such cases it was necessary to superimpose higher priority military requirements. Not only did machine tools, components, and aircraft parts become bottlenecks but labor strikes also affected production output.

The important element of lead time, the interval between placing an order and the delivery of a finished product, continues to be a controlling factor in military aircraft production. The great production effort of the Korean War did not materialize until the summer of 1952, two years after orders had been placed with the aircraft companies. In that year the lead time on a modern fighter amounted to approximately two and a half years, while a bomber took about three years. The reasons for the long lead time required are shown below in the treatment of the nature, organization, and operation of of the industry.

RGANIZATION AND DISTRIBUTION OF THE U. S. AIRCRAFT INDUSTRY

Typical aircraft making methods are not f the mass production type prevalent in the utomobile industry. Nor can they be put in e "tailormade" category of production hich is characteristic of the locomotive and ipbuilding industries. Rather they are in- rmediate between these two types. Mass roduction methods cannot generally be sed in building air vehicles because of the uge size of some planes, the great variety f models, the small number produced of me types, the rapidity of technological rogress, fast-changing designs, restricted arkets, and fluctuations in production. nly during periods of extremely high out- ut have mass production methods been used ith some success, as during the latter years f the Second World War.

anufacturing Processes and rganization

The function of designing is of crucial im- ortance in building airplanes and missiles. pecial-purpose characteristics of planes great speed, high altitude ceiling, or long ange) and rapid technological progress in e industry impose great demands on de- gners and practically preclude standardi- tion. Designing, plus developmental and sting work which follow, involves the ex- enditure of large quantities of high-salaried bor. The costs of these preliminary phases re spread out, as a rule, over a few operat- g models. For these reasons total unit costs for aircraft run high. Complicated planes of today require several years from the drawing board to the operational stage. This time lag tends to become greater as air and space vehicles become more and more complex.

The manufacturing processes are similar to those of other metal fabricating industries. Component parts are produced by numerous independent suppliers from many facets of the American industrial economy. Such subcontracting is typical of the so-called non-integrated type of manufacturer.[9] Still there are a few manufacturers of the integrated type. They possess all essential manufacturing facilities, including a combination of subsidiary companies, allowing them to make a complete plane. United Aircraft and Curtiss-Wright Corporation are examples of this type.

Aircraft industries are also much more dependent upon multipurpose tools and equipment than are mass-producing industries. With such machines they can, of course, turn out a wider range of models and parts without retooling than can mass production industries. Moreover, multipurpose equipment enables a manufacturer to meet more adequately the exigencies of a rapidly changing technology and the requirements for precision. However, the complexity of the equipment requires the employment of highly skilled workmen to an extent not encountered in mass production industries.

Precision machining, for instance, is absolutely essential in the aircraft industry. This function involves the use of the most advanced techniques for the machining itself and for discerning both internal and external imperfections. Highly skilled workmen and expensive equipment are also required for the inspection phase of production. Although this assures high perform-

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[9] Non-integrated manufacturers are independent concerns which accept orders for aircraft parts and which also make parts for other industrial products, such as automobiles.

MILITARY AIRCRAFT DEVELOPMENT SCHEDULES

Type of aircraft	Development [1]	Testing [2]	Production [3]	Operational [4]
Bombers:				
B–17	1933	1936	1937	1941
B–29	1938	1941	1943	1944
B–47	1942	1946	1950	1952
B–52	1946	1952	1954	1954
Cargo:				
C–97	1942	1944	1947	1949
KC–135	1947	1951	1956	1957

[1] Date aircraft industry or Air Force first established specifications.

[2] First prototype ready.

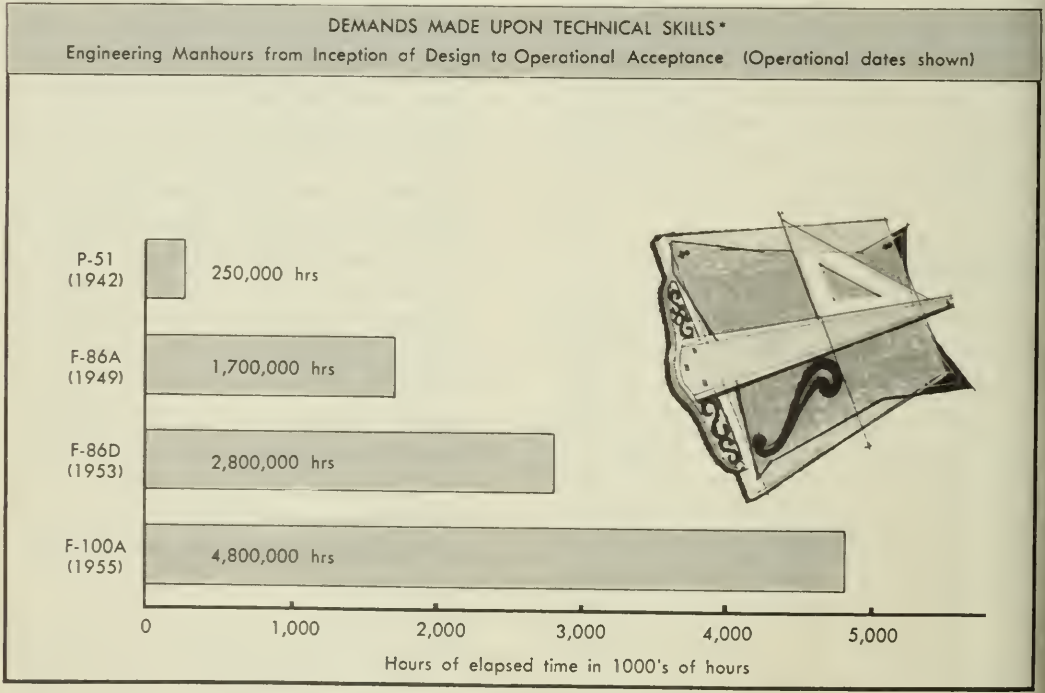
[3] Date first production model left factory or first delivery.

[4] Assigned for operational use by Air Force.

ance in the finished product, it again increases the unit cost of that product.

One of the major considerations in locating an aircraft manufacturing plant is this need for many highly skilled workmen technically competent to handle complex machine tools and perform much hand assembly work. Of course large numbers of engineers, draftsmen, and research workers are also needed. The plants are usually located near or adjacent to large centers of population. Costs in such areas are generally high and must be reflected in the final product.

The aircraft industry uses the sub-assembly system as does the automobile industry. Unit assemblies move from one work station


DEMANDS MADE UPON TECHNICAL SKILLS*

Engineering Manhours from Inception of Design to Operational Acceptance (Operational dates shown)

*Adapted from 1st report Senate Preparedness Subcommittee (1954).

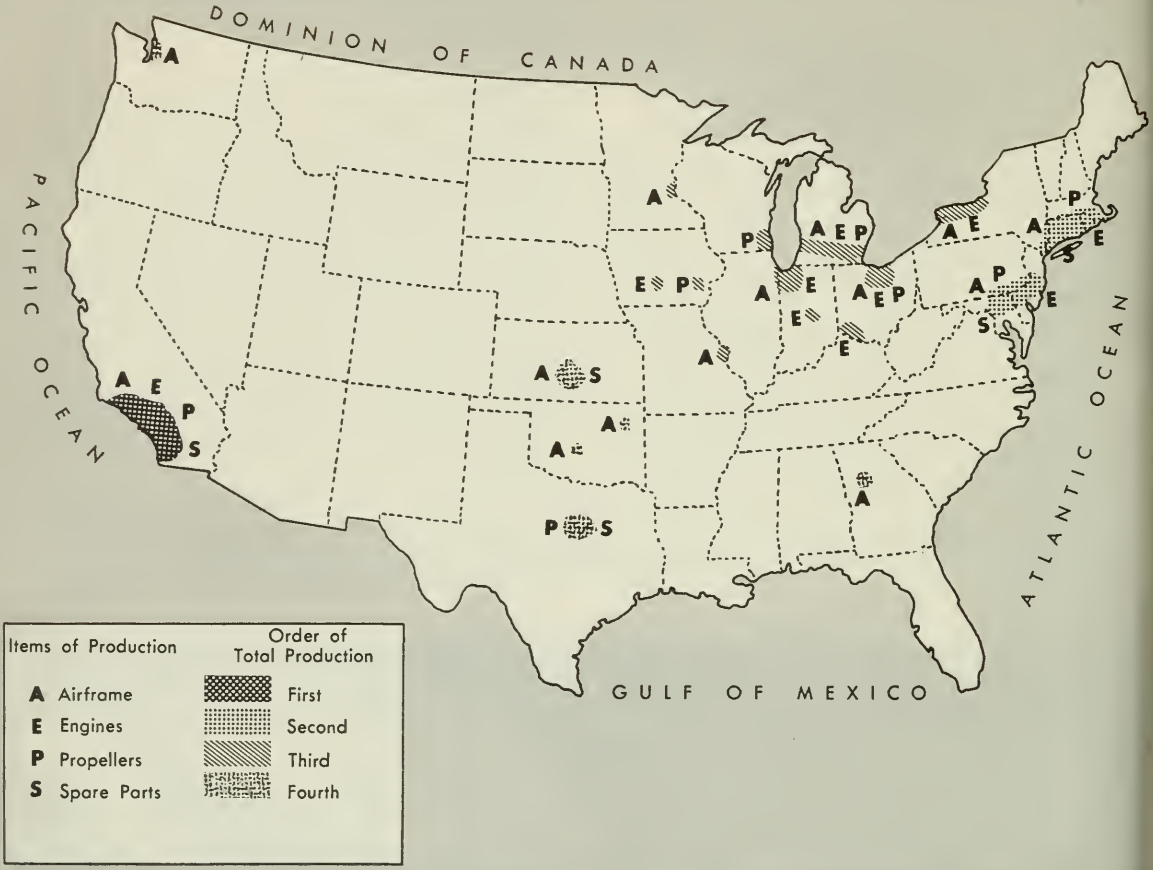
o another. As many as twenty work staons may be involved. The line sometimes emains stationary for hours while workers omplete unit assemblies and sub-assemblies n each airframe in different stages of comletion, utilizing much hand labor in these rocesses. A distinguishing characteristic f the assembly line is its intermittent movelent compared with the continually moving ne in mass production industries.

Based upon the type of work done, there re four groups of plants or factories enaged in the conventional aircraft industry. hey include (1) airframe plants, (2) enine factories, (3) propeller factories, and 4) equipment making plants. These plants re widely scattered over the United States.

Distribution of the Industry in the United States

Traditional location factors have been relatively unimportant in the aircraft industry because of the light weight of its raw materials, mobility of the completed airplane, and the government subsidy of the industry, in conjunction with a major emphasis on skilled labor pools necessary for the complex manufacturing processes. Nevertheless, some locational pattern is discernible. Southern California leads in airframe production; and the East, with its heavy metals know-how, leads in engine production.

overing more than 56 acres of floor space, these buildings comprise the main plant of the Hughes Aircraft ompany at Culver City, California. To the left is the Hughes runway, one of the longest in the world. Beond it is the residential section of Culver City. In the foreground is the Loyola University Chapel.



Along with skilled labor supply, climate is a major factor in the location of aircraft plants when political or strategic considerations are not overriding. A warm, dry climate, such as that of Southern California, is most desirable. In that climate year-round flight testing is possible, storage of parts out-of-doors is feasible; heating requirements for the huge buildings are minimized; and work out-of-doors is possible throughout the year. These factors all tend to lower production costs.

Taxation is another consideration in industrial location. Because of high taxes on urban property, and the high unit value of such property, aircraft plants generally locate on the peripheries of the metropolitan districts to reduce overhead costs as much as possible. For example, the Southern California plants are located at Inglewood, Hawthorne, Long Beach, Santa Monica, and at other cities adjacent to the labor supply of Los Angeles, but none of them is in Los Angeles.

Nearness to military proving grounds and training sites is yet another locational factor. Texas and California are both well-endowed with Air Force bases and are also the two leading states in the aircraft industry.

Sources of raw materials, transportation facilities, and power sources appear to exert little influence on the precise location of aircraft factories in the United States. This is direct contradistinction to most heavy industries which are located first of all near power sources, and secondarily near raw marials, transportation facilities, and markets.

utlook for Aircraft Industry in the U. S.

The aircraft industry from its inception as been characterized by high cost production and narrow profit margins—or even perating losses. This situation is now agavated with the advent of complicated anes utilizing radar, gas turbines, jet opulsion, and intricate electronic equipent. It presently costs millions of dollars develop a new model; thus, either high ices per production unit or a large outit is necessary to recover the investment in y given model. The high cost of conntly developing ever better military air hicles could hardly be borne by any buyer cept the government. Commercial planes ed on the airways and in general aviation not change nearly as fast as military craft.

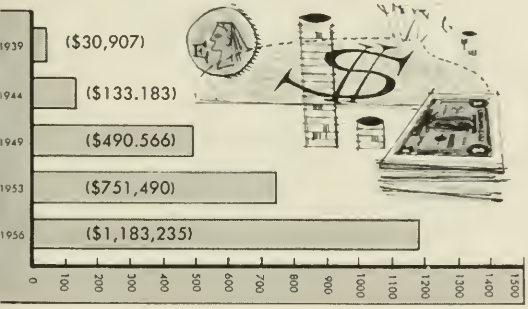
evertheless, as will be seen in the airlines apter, the tempo of change in commercial ansports is fast—the airlines alone having aced orders for several billions in new uipment during the middle 1950's.

Orders for military planes will, as in the st, remain uncertain. Hence businessmen nnot make much use of them for projectg firm production trends. Most military nstruction will continue to be closely reed to the rapidly changing international uation. A sizeable amount of production for some companies, however, consists of civil aircraft for passenger and freight transportation and for pleasure use and utility. In 1956 the industry produced more civil aircraft than military. Nevertheless, the immensity of military output—both in value and weight of aircraft—dwarfed civil aircraft production.[10] This trend seems likely to continue for the foreseeable future. And of course civil aircraft business has scarcely any effect on those companies which work almost entirely on military orders.

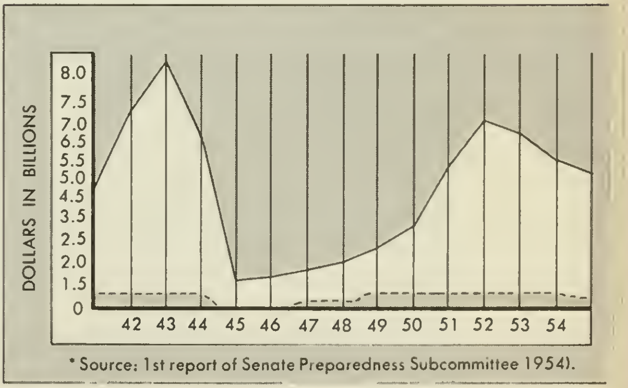
It appears that the greatest impact on the United States aircraft industry in future years will be in the area of missile development and production. The extent of United States participation in the expansion of missile and space vehicle production is well illustrated by some recent comparisons. In 1951 the United States spent $21 million on missile procurement; in 1957, this expenditure amounted to almost $2.9 billion.

Some aircraft companies started research on guided missiles at the end of the Second World War. Since that time, many of them

ERAGE COSTS FOR MILITARY AIRCRAFT UNITS BY SELECTED YEARS
(Dollar Figures in Thousands)



DOLLAR VOLUME AIRCRAFT SALES *



* Source: 1st report of Senate Preparedness Subcommittee 1954).

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[10] See the following tables in *Aviation Facts and Figures*: U. S. Airframe Weight Production (Military and Civil), 1939 to Present; Aircraft Engine Production (Military and Civil), 1917 to Present; Sales by Manufacturers of Complete Aircraft, Aircraft Engines, Propellers and Parts, 1948 to Date (Millions of Dollars).

have added missiles to their regular aircraft production output. As shown earlier, American aircraft industries are well dispersed and located in four major regions. The location of missile plants in the United States follows this same pattern. Often the plant facilities for aircraft and missile production are located in the same area.

Looking to the future, one can do little more than speculate. On the basis of the record, however, it is safe to say that the aircraft industry will respond well to the demands placed upon it under a system of relatively free economy. Both the achievements and the problems facing American aircraft and missile producers may be viewed with clearer perspective, however, by making a survey of aircraft industries abroad.

UNITED STATES AIRCRAFT PRODUCTION*

Years	Military	Utility	Transport	To
1939	2, 195	3, 555	106	5
1944	96, 318	N/A	N/A	
1949	2, 544	3, 379	166	6
1953	11, 000	3, 825	309	15
1956	6, 800	6, 778	428	14

*Years were selected on the basis of available data all types of aircraft.

FOREIGN AIRCRAFT INDUSTRY

The Soviet Union

It is obvious that Russia's capabilities in aircraft production were not acquired in just the last decade. In the early years of aviation history, the Russian aircraft industry was comparable to that of the Western powers. At that time designers like Sikorsky were making important contributions to aviation development. The inefficiency and corruption of the Tsarist regime, the collapse of the Russian armies in 1917, the overturning of the social order, and civil war—all these events conspired to produce famine and prostrate the economy by 1921. They led most foreign observers to form a distorted mental image of Russia which persisted to the 1950's, despite Soviet military and industrial progress. The Soviet Union's dependence on foreign technical help for her early Five Year Programs confirmed the opinion that the country was basically weak in technology. With the rise to power of militarists in Germany and Japan, Soviet armament and aircraft industries mushroomed. In 1941, however, the Nazi invasion abruptly disrupted aircraft production in European Russia. Many plants were moved eastward to Siberia. Nevertheless, production during the war years was high, reaching a peak of 56,000 in 1944.

During the war the United States and Great Britain shipped billions of dollars worth of military equipment and supplies including aircraft to the beleaguered Soviet Union. This materiel was put to good use as the Red Army, despite immense losses, stood up under the hammer blows of the *Wehrmacht*. In the process the Soviets naturally learned much about advanced Western equipment and materially improved their technology. However, their efforts to catch up with the West in this area of achievement went to extremes in some cases. Even American bomber crews which made forced landings in friendly Soviet territory during the war were held for varying periods of time, and their aircraft taken from them. In this way, for instance, the Soviets obtained data on the most advanced operational U. S.

bomber of the war—the B–29 Superfortress. This plane soon made its appearance in the postwar period as the TU–4 (named after Tupolev, a leading Russian designer).

After the close of the Great Fatherland War, as Russians called the Second World War, thousands of German technicians, scientists, and skilled workers were pressed into industrial service and research on jet planes and missiles. Sometimes whole factories were moved, together with personnel. Postwar sales of Western aircraft products such as the British Nene jet engine also speeded aeronautical development in the USSR.

The Soviets were also able to draw upon other foreign sources, openly or covertly, thus stepping up their rate of progress in the aeronautical art. Undoubtedly they could have done the job themselves, but it would have taken more time. By the time the Russians felt themselves able to get rid of direct foreign assistance, their aircraft industry had reached considerable proportions. Beginning in 1950 Soviet aerial activity demonstrated to the world that they had built secure foundations for a strong and efficient aircraft industry. Before long Soviet scientists were able to make original contributions of the first magnitude in rocket propulsion and astronautics.

Distribution of Soviet Aircraft Industry.

This industry is apparently concentrated in four principal areas: (1) the Volga River Valley in European Russia, (2) the Moscow area, also in European Russia, (3) the Kuznetsk Basin in Western Siberia, and (4) the Komsomolsk region in Eastern Siberia. These centers produce many types of manufactured goods besides aircraft.

The major factors determining the location of aircraft industries in the USSR are resources and transportation, though strategic considerations are evident. Despite the fact that the USSR lacks good transportation facilities in many areas, it should be noted that these major aircraft producing areas are on or near the Trans-Siberian railroad system. The buildup of the aircraft industries in these four key centers increased their labor and raw material requirements; the labor problem was apparently resolved in part by impressment and transfer of large numbers of skilled technicians.

SOVIET AIRCRAFT PRODUCTION (OUTPUT)*

Pre-war				Post-war				
Year	Estimated total	Year	Estimated total	Year	Bombers	Trainers	Fighter	Transport
1928	650	1937	7, 540	1948	600		2, 400	
1929	980	1938	10, 000	1949	5, 000		4, 500	
1930	1, 100	1939	10, 000	1951		600	11, 000	1, 200
1931	1, 500	1940	10, 000	1952	1, 800	5, 000	15, 400	1, 400
1932	1, 920	1941	10, 000					
1933	2, 800	1942	17, 500					
1934	4, 000	1943	24, 000					
1935	5, 400	1944	56, 000					
1936	7, 000	1945	40, 000					

Approximately 2,000 other types of aircraft have been produced, including: search, rescue, liaison, etc.

All figures shown are western countries' estimates and not verified figures.

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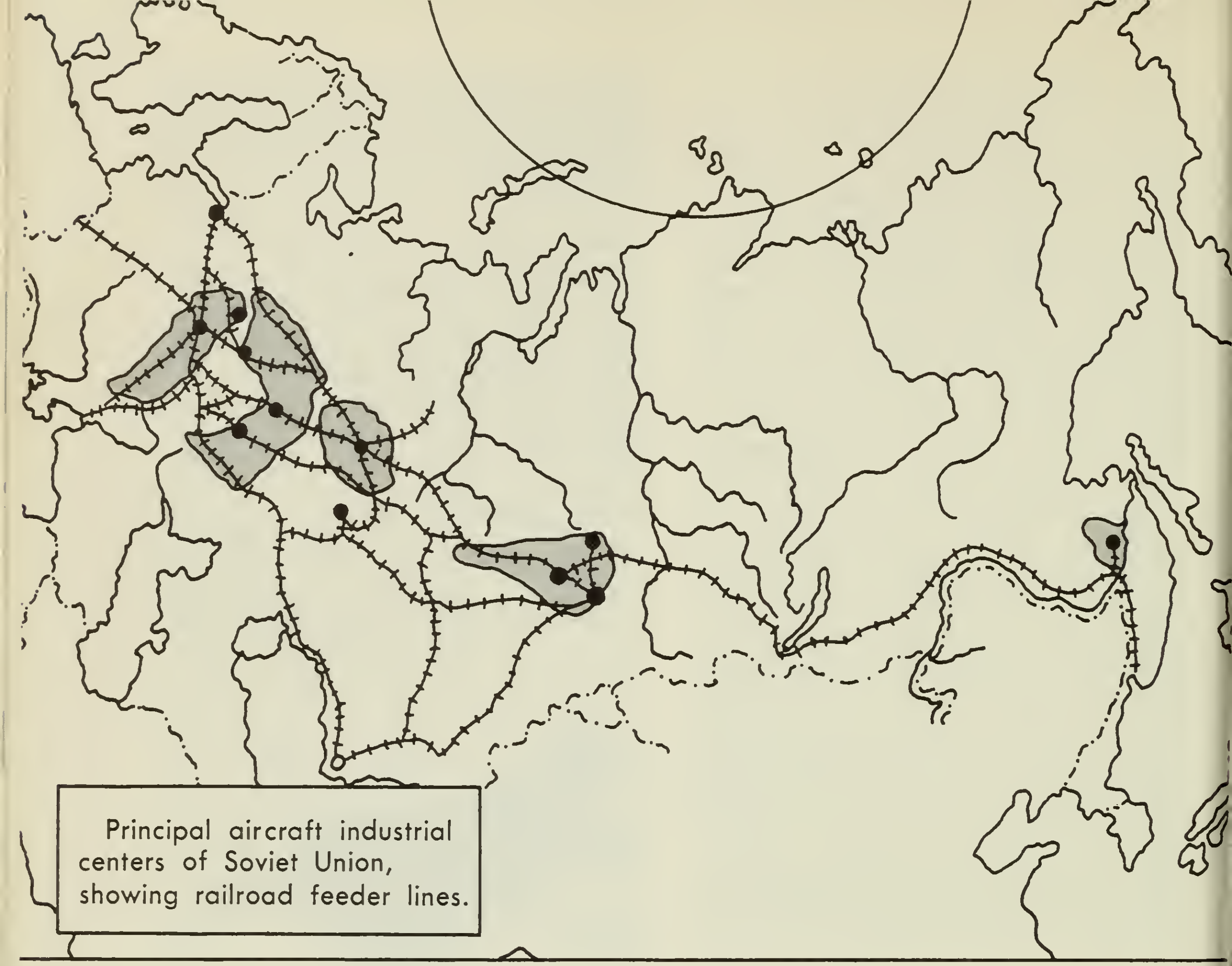
*Adapted from "The Soviet Aircraft Industry," Institute for Research in Social Science, University of North Carolina, Chapel Hill, N. C., 1955, pp. 90, 95.



Principal aircraft industrial centers of Soviet Union, showing railroad feeder lines.

The aircraft industry of the USSR is directed, controlled, and financed directly by the government. Plants in the Soviet aircraft industry are integrated in a manner designed to insure a continuous flow of products. This system has reportedly produced good results, although handicapped by antiquated methods, insufficient specialized equipment, and lack of automation.[11]

Educational Support for the Soviet Aircraft Industry [12]

The Soviet air development program is wide in scope and unhampered by budgetary restrictions. Pushing progress on a broad front at a maximum rate is apparently the primary objective. This is borne out by the educational effort; here top priority is given to training scientists and engineers of the quality and in the quantity needed.

Soviet scientific and engineering schools are graduating larger numbers of young people than American colleges and universities. Most of the graduates are tagged for employment in industries producing military products. The aircraft and missiles industry is naturally high on the priority list for such key personnel.

Although Russian scientists and engineers cannot move around at will, they are treated with honor and are offered attractive incentives. Ability is rewarded with promotion. Outstanding designs are given the designer's initials. Top scientists receive good salaries, even by Western standards. Based on available evidence, it appears that working conditions for technicians are comparable to those in the American aircraft industry.

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[11] Institute for Research in Social Sciences, University of North Carolina, *The Soviet Aircraft Industry* (Chapel Hill, N. C., 1955).

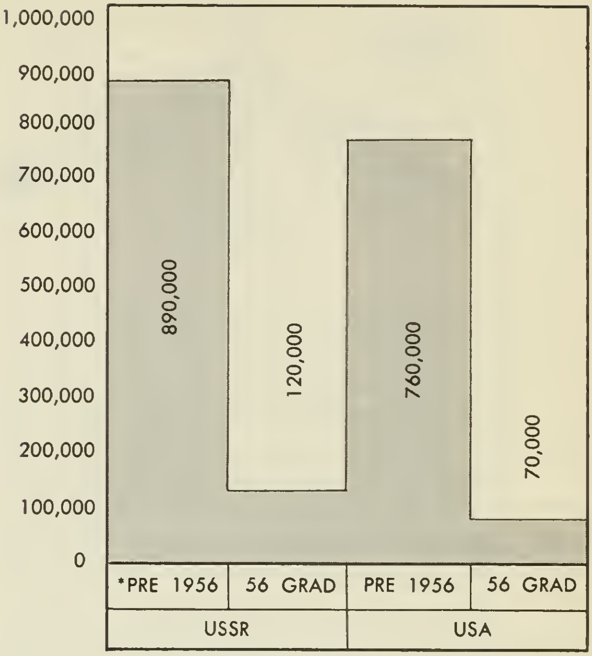
[12] This section is based on the Chapel Hill study cited above.

The chief aviation institutes and schools are under the jurisdiction of the Ministry of Aviation or allied industries. Most of them are located in the capital. In addition to the special research and testing centers, aviation research is also conducted in many individual plants of the aircraft industry. Beyond this, other research bodies including universities are often assigned work which has a direct bearing on aeronautics. They may be given work to do for the Soviet air force or the civil air transport fleet, or for industries engaged in parallel types of aeronautical development. Several divisions of the Academy of Sciences also participate in aviation research and astronautics.[13]

The general objective of the higher aviation educational institutions is to prepare engineers and technicians for employment in the construction of aircraft and aircraft engines, armament systems, instruments, and radio-navigation equipment. They are also expected to contribute to general technological development and to improve the organization of production in the aircraft and missiles industry. Almost all of these institutions carry on scientific-research activities. In this work both staff and advanced students participate.

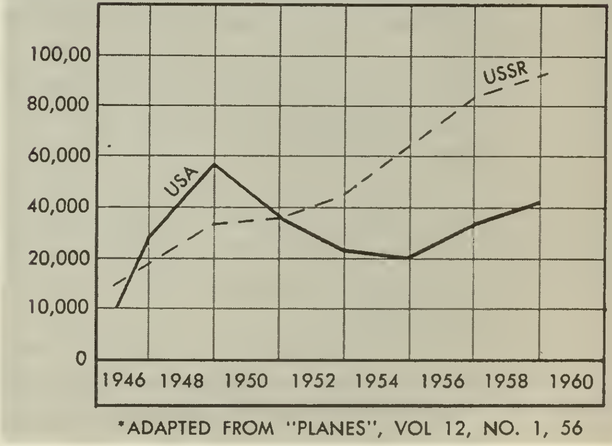
Its great emphasis upon science, engineering, and technology has made the USSR a leader in aeronautical engineering and in the production of aircraft, and more recently one of the foremost powers in the realm of guided missiles and space vehicles.

SCIENTIFIC PERSONNEL*



*ADAPTED FROM "PLANES", VOL 12, NO. 1, 56

COMPARISON OF USSR AND USA ENGINEERING GRADUATES*



*ADAPTED FROM "PLANES", VOL 12, NO. 1, 56

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[13] The secretary of the Commission on Astronautics, Academy of Sciences attended the Barcelona congress of the International Astronautical Federation in 1957. (Erik Bergaust, "Russia's Moon Rocket Program," *Missiles and Rockets*, Vol 2 [November 1957] p. 37)

The British Commonwealth

Australia, Canada, and Great Britain are the only members of the British Commonwealth that presently have important aircraft industries. Working together, they enable the British to maintain third place among the world's air powers. Although the potential of each of these states is generally evaluated separately, it should be kept in mind that the individual national capacities undoubtedly would be combined if any of them were gravely threatened or attacked.

Australia is the least productive of the three. It has some natural resources for an aircraft industry but, more importantly, it is near areas that are especially rich in some minerals and metals that are essential to aircraft construction. Canada has key resources in great quantity. The United Kingdom has a wealth of industrial facilities. Because of these diverse and well distributed advantages, the three Commonwealth nations can only rely on a supply of resources that is perhaps as great as either the American or Russian.

The total output of British, Canadian, and Australian aircraft industries is considerably less than that of the United States or the USSR, but the quality of products is comparable.

The United Kingdom's emphasis on missiles may have a significant effect on her ability to produce commercial aircraft. Many plant facilities which were developed to fill the needs of the RAF are being converted to missile production. Scientists and engineers who have been engaged in development and research on military aircraft and associated equipment may transfer to the missile field. Yet it is probable that some existing plants, especially those which formerly made engines for military craft, will continue commercial projects and retain some scientists, designers, engineers, and a portion of the skilled labor force. Indirectly, the financial factor may tend to encourage production of commercial aircraft for export. In addition, the government hopes that concentration on missiles will permit reduction of the military budget, thus directly assisting in the problems of national finance.

Canada's aircraft industry was begun virtually by government fiat ten years ago. Today it is the third largest employer of labor in the country. It supplies not only a formidable and modern air force but also manufactures planes for export.

Though prospering, Canadian aircraft producers encounter problems similar to those in United States industrialists. For example, they suffer from a fluctuating military requirement. Current problems are caused largely by the industry's need to break away from dependence on government orders and yet obtain some simultaneous government support for expansion of its commercial export market.

West Continental Europe

Aviation prospects for West Germany are on the rise. The Germans are making steady progress in rebuilding their air force and airlines, and have also obtained large foreign orders for military and commercial aircraft. Manufacture of many of these aircraft will be based on foreign designs until the Germans once more develop their own. With the Federal Republic's tremendous technological and industrial potential to draw upon, the aircraft industry has a bright future.

French aircraft makers are struggling to regain their prestige in the aeronautical world. The outlook, though, is not too promising because of government instability and a weak financial structure. Production for the French air forces is considerable. The industry also has large foreign orders. Like several other nations outside the Big Three, the French are planning to develop atomic weapon capabilities for their air and other military forces.

In 1957 the structure of the French airframe industry underwent significant change when two large state-owned firms were merged. One was Sud Est, which employs 12,000 workers. The other was Ouest Aviation which has 10,000 employees. The merger left only one other nationalized airframe company—Nord—an employer of 8,000 people.

The Italian aircraft industry's recovery is not adequately reflected in the volume of annual production. In 1956 Italian producers employed hardly more than 4,000 workers and sold only $35,000,000 worth of aircraft at home and abroad.

Although this output is not impressive, it nevertheless marked a 25 percent gain over the previous year. More significantly, most of the products—both military and commercial—were Italian in design as well as manufacture. These facts show that the Italian industry—like the German—is beginning to regain its pre-World War II capabilities. However, its resource base is much poorer than Germany's.

In Northern Europe, lying along the Russian-controlled Baltic Sea, Sweden depends heavily for its national survival upon its own air force. It is both modern and sizeable. Not only are Swedish air force units based underground, but many of the planes used are built in factories blasted out of rocks lying below the surface of the earth. These plants are air conditioned and supplied with raw materials brought in through long descending tunnels. Facilities are designed to operate even during gas attacks.

Production carried on both above and below the surface already has given Sweden a combat air force of almost 1,200 jet planes. The supersonic J–35 Draken fighter is scheduled for use in Swedish military aviation by 1959. An interceptor missile has been under development for some time. Furthermore, the purchase in 1955 of Australian Jindivik pilotless target aircraft indicates that the Royal Swedish Air Force is preparing to use air-to-air missiles. If air-to-ground missiles are also to be employed, as reported, it reflects Swedish determination to employ air power offensively if war should come.

In the Low Countries, the Netherlands has aircraft plants at Ypenburg, Amsterdam, and Woendrecht. They produce both military and commercial craft for domestic and export sales. This industrial complex makes civilian turbojet aircraft, military jet planes, and guided missiles. It also converts older military transports to civilian commercial use. One firm limits itself largely to repair and maintenance work for the Royal Dutch Air Force.

Though it is one of the world's most highly industrialized countries, Belgium is a minor producer of aircraft. The firm of Stamp and Renard near Brussels makes a domestically designed primary trainer on a limited scale. Hawker Hunter jets for the Belgian and Dutch air forces are produced under license by several engine and aircraft plants in the Low Countries.

Farther south is another small producer—Switzerland. The Swiss are famous as makers of precision instruments for manufacturing and operating aircraft. They also make engines and assemble airplanes. Their aircraft industry is preparing to include the complete manufacture of jets for use by Swiss military units.

Spain, in the southwestern part of the continent, started comparatively late in the aeronautical field. Spanish aircraft facilities are devoted primarily to making light planes and assembling aircraft purchased abroad.

Asia

Japan possesses the technological ability and the industrial base needed for the manufacture of aircraft and missiles. Like the Germans, the Japanese are temporarily handicapped by postwar lack of industrial experience in these fields. As a result, the manufacture of complex parts was initiated with technical aid from American firms. Japan announced in 1957 its intention to start its own missile production. Japan's major concentration, however, is on military aircraft. Some firms make jet engine parts and others produce entire engines. Several companies of the integrated type produce finished planes—airframes, engines, and instruments. The industry, however, is handicapped by a weak resource base; many raw materials must be imported, often at high prices.

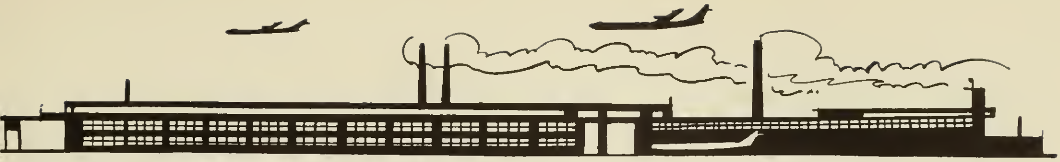
Except for Japan, industrial development in non-Soviet Asia has been extremely slow but an industrial awakening is in the making. Neither India nor Communist China has immediately available a fund of capital and technical knowledge sufficient for extensive production of aircraft or associated electronic aids. However, both countries are not only rich in strategic metallic ores but also have undeveloped coal and water resources which could provide the necessary power to operate new plants. Each of these huge nations already has one or more centers of heavy industry—China in Manchuria and India in the Bihar-Orissa area. These centers, besides others reportedly under development in China, have the resources and industrial base needed for aircraft and engine manufacture.

The entire output of China and India is as yet of minor importance on the industrial scene. However, their potential for aircraft production could become a significant factor in world affairs within a matter of decades. In the interim period, these and other non-Soviet countries of mainland Asia remain dependent upon outside technical and financial assistance in operating their aircraft industries; to adequately meet their military and civilian aircraft needs, they must at the same time import finished craft.

Latin America

Throughout Latin America only Argentina and Brazil presently support aircraft industries. Mexico and Chile are believed to have the necessary potential for future aircraft industrial development.

In Argentina, the IAME plant at Cordoba employs 8,500 people. It assembles trainer aircraft purchased from other countries. Formerly, however, it manufactured various models of light planes; it expects to resume such production.



TRENDS AND PROSPECTS IN THE AIRCRAFT INDUSTRY

In this age of jet airplanes, intercontinental supersonic missiles, and earth girdling satellites, major segments of the aircraft industry are being forced to make substantial readjustments and changes. Companies working largely on military orders will probably be forced both to centralize their operations and diversify their production. It seems that only by such means can they reduce unit production costs sufficiently to carry them successfully through slack periods—those periods when military orders are reduced.

In conjunction with military research and development organizations, the aircraft industry of the future may be expected to devote funds and personnel to research on an unprecedented scale. Much effort is required in the realm of pure research to solve space and speed problems connected with development of newer and better electronic systems, guidance mechanisms, fuels, and materials.

Changes from the standpoint of business organization point in the direction of a more highly integrated industry with less dependence on the often financially unstable subcontractor; concentration of operations in fewer plants for reasons of economy; and more diversified commitments in related fields of missiles and aircraft for protection from the boom and bust cycle.

Demand for highly skilled workmen, technicians, and engineers may be expected to grow rapidly as the industry becomes increasingly involved in manufacturing complex missiles, satellites, and related items. In turn, the responsibility placed upon institutions of higher learning to provide the necessary scientific and technical training is a challenging one and demands the marshalling of the best intellects for its resolution. Industry itself is being forced to provide more extensive and up-to-date technical training programs for its personnel than in the past.

Apart from the transcendent issue of national survival, the jobs of thousands of workers and the fortunes of thousands of investors are involved in the maturation of the aircraft industry. During this transition period many economically unstable firms are in danger of failing, or may fail, as was the case in the automobile and appliance industries as each of them attained maturity. Indications are however that the aircraft industry as a whole will emerge stronger, more flexible, more diversified, and more completely interwoven with the whole economy than during its earlier years. In any case, its leaders, scientists, engineers, and skilled workmen may be counted upon to produce the superior air vehicles needed to shield the nation.

In the world at large, only the industrial giants—the United States and the Soviet Union—will be able to afford full programs in all fields of the newly emerging version of the air vehicle industry. The staggering cost in capital equipment, materials, and labor will exclude all others. Already the United Kingdom has largely withdrawn from specialized military aircraft production and is concentrating its limited resources upon missile production. Such trends have important political overtones. The pooling of British and American scientific efforts certainly makes it clear that, within the free world at least, nations can no longer operate independently of others in building defense structures. In a world unable to agree on disarmament controls, the law of self-preservation makes it imperative that the free nations conjoin their efforts to design, build, and operate military air and space craft which will assure them control of the air and common survival.

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PART 1

CHAPTER 5

Airlines and Airways

Every day thousands of aircraft of various types ply the skies. Huge airliners regularly carry passengers and mail hundreds of miles. Cargo planes move tons of freight long distances in a matter of a few hours. Helicopters whirl their loads over congested city streets. Planes carry businessmen to appointments from one region to another and back before the end of a normal business day.

Quite obviously aviation has had a great impact on daily civilian life. Part of its influence comes from regularly scheduled air transportation commonly referred to as *airline flying*. Non-scheduled flying activities in business and agriculture, contract cargo transportation, industrial aviation, flight instruction, and sport or pleasure flying similarly affect much of our daily life. Non-scheduled flying is generally referred to as *general aviation* and embraces both commercial and private flying. Together, airline flying and general aviation constitute *civil aviation,* which includes all types of flying except military flying.

In less than half a century civil aviation has grown to maturity under the stimulus of war and the paternal guidance of the Federal Government. Virtually every contribution of research to military aviation is ultimately reflected in the progress of civil aviation. At the same time the Government has directly and assiduously fostered the growth of civil aviation, particularly in the lean early years. Today the airlines—the most important component of civil aviation—are rapidly approaching a point of financial independence.

Civil aviation is a major element of airpower. A nation's ability to use its airspace is measured by the density of its civil air traffic. Civil aviation occupies an integral position in the larger complex of national air power and contributes in important ways to the security of the nation.

The airlines in particular furnish immediate airlift capacity which can be used for military or other emergency use. To a lesser degree irregular contract carriers and numerous private business planes are also available for such use. Moreover, fast flying transports greatly facilitate the conduct of the nation's business—private and governmental. In time of crisis this service has proved indispensable. Again, the airlines and general aviation contribute significantly to the strength of the nation's air power structure by the demand they create for improved aircraft and up-to-date air facilities. Such business is invaluable to the aeronautical and electronics industries, some of which suffer from fluctuating military demand for their products. At the same time civil aviation—particularly the airlines—continually adds to the nation's fund of flying experience and skill. Most important, however, is the military airlift capability of the civil air fleet.

Thus a direct correlation exists between the status of the aeronautical industries and technological progress on the one hand, and the efficiency of the civil and military air establishments on the other. Both airline flying and general aviation are dependent for their success upon the aeronautical industries and the state of technological development. This interdependence is well expressed by John C. Cooper, an authority on air power, who said, "The development of any use or phase of national airpower develops the potentialities of every other use of air power." [1]

Throughout this course the student should endeavor to keep in mind the interrelationships between the major elements of air power and seek to apply them to his own and other countries. Emphasis will be placed on the extent and variety of the peacetime uses of civil aviation, both in the United States and abroad, and the evolution and future of the air transportation industry in terms of technological, economic, and military factors.

AIRLINE FLYING

In spite of the fact that airline flying represents only a small portion of civil aviation, it has a more direct influence on our daily lives than either general aviation or military aviation. Regularly scheduled airliners are a common sight. Constant advertising keeps airline flying in the public eye. More and more people are using the airlines for business and pleasure. To the general public the commercial aircraft is the most obvious element of the air age.

Airline flying is the transportation of passengers and cargo by airlines operating as common carriers just as do railroads, trucks, and buses. In other words, airlines serve the general public by means of fixed routes according to regular timetables and published fares. As common carriers they are subject to governmental regulation, particularly in matters of establishment of routes, schedules, fares, and number of carriers. Airlines are controlled by the Civil Aeronautics Administration, much as the railroads are regulated by the Interstate Commerce Commission. One airline cannot charge one fare between New York and Chicago, and another a different rate. Nor can airlines establish new routes or add new flights without governmental approval.

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[1] John C. Cooper, *The Right to Fly* (New York: 1947), p. 204.

Governmental controls are designed to give the public reliable air transportation and protect individual companies from unfair competition. Control is also dictated by military needs. Just as railroads play vital defense roles during wartime, airlines similarly are called upon to move troops and cargo. During the Korean War, commercial airlines speeded thousands of troops and many tons of cargo across the Pacific. Airlines provide an important reservoir of military air power.

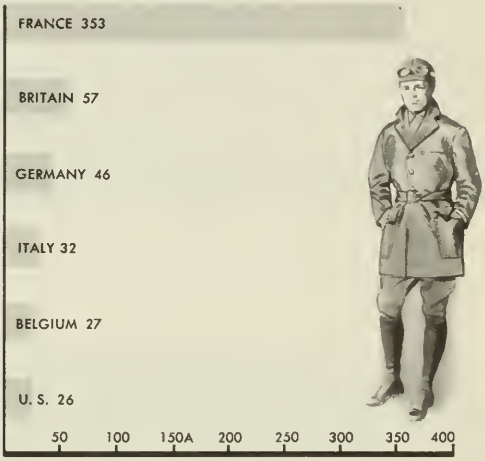
Air Transportation and Air Power

The basic theme of air power is fast transport, the movement of men and material through the air. The cargo may be commercial freight or atomic bombs, fare-paying passengers or troops. The air vehicle may be operated by a civil airline or by a military service. Regardless of land obstables or ocean expanse, the function of air power is to move men and cargo rapidly from one point to another.

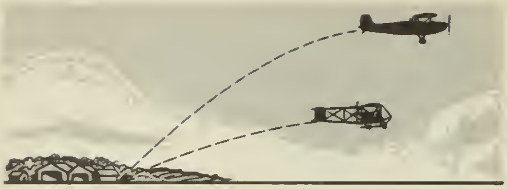
General "Hap" Arnold emphasized the connection between air transport and air power in his final report as Commanding General of the Army Air Forces in World War II. In this report he said, "Air power includes a nation's ability to deliver cargo, people, destructive missiles and war-making potential through the air to a desired destination to accomplish a desired purpose. Air power is the total aviation activity—civilian and military, commercial and private, potential as well as existing."

Beginnings of Air Transportation

The flight of the Wright brothers in 1903 marked the dawn of a new era in transportation and human affairs. Progress in air transportation was almost immediate, particularly in Europe. Shortly after the Wright brothers made their memorable flight, Henri Farman, a Frenchman, made aviation history by taking up the first passengers in an airplane. A little later Louis Blériot, another Frenchman, flew across the English Channel. Aside from being a notable aviation achievement, Blériot's flight marked the beginning of the end of Britain's policy of "splendid isolation" from the continent. European enthusiasm for aviation in those early years was also highlighted by the establishment of international speed races at Rheims. Here leading European governments offered prizes for improved aircraft engines. The world's first true aircraft factory was built in France in 1911. Rapid acceptance of the airplane in Europe is indicated by the number of licensed pilots in 1911. In that year, there were 353 licensed pilots in France, 57 in Britain, 46 in Germany, 32 in Italy, and 27 in Belgium. In that same year there were only 26 licensed pilots in the United States.



Although the United States had only a few pilots in 1911, interest in aviation was not completely lacking. In 1908 the Army Signal Corps contracted with the Wright brothers for its first airplane. Two years later Glenn Curtiss flew an aircraft from New York City to Albany, a remarkable feat for the time. In 1911 American fliers completed the first continental flight across the United States. The trip naturally was not non-stop, but rather a series of short hops. Nevertheless, it served to emphasize the potential of the airplane as a means of transportation in the country.



By World War I the airplane itself had taken on the basic features of the modern aircraft. The fuselage was enclosed, landing wheels were added, and more efficient power units were installed. Improved power plants enabled pilots to climb higher. By 1914 planes reached altitudes of 26,000 feet. In 1909 the ceiling was around 1900 feet.

Air Transport in World War I

The tremendous impetus of World War I brought about technical advances in aviation which would have been impossible in a decade of peace. Engines were improved, and multimotored aircraft were designed and put into operation. The airplane proved its value not only in reconnaissance but also in interception and bombardment. Before the war ended, air transportation had proved its value as a weapon of national defense. The British Royal Air Force started the first scheduled air transport service in May 1918, with a regular run between London and Paris. Intensive wartime research vastly improved air transport performance in terms of power, speed, and reliability.

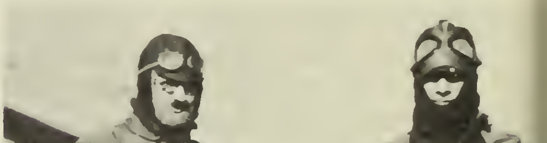
Origin of Scheduled Air Transportation

The military and commercial advantages of the airplane prompted most European governments to subsidize commercial air transportation, resulting in the establishment of many airlines. By 1926 the combined airlines of the United Kingdom, France, Germany, Italy, and the Netherlands carried 100,000 passengers a year, logging over 9 million passenger miles. Passengers of American nationality predominated on the most popular routes, such as the one between London and Paris. In the United States, however, scheduled airlines did not provide regular passenger service even as late as 1926. Such passengers as were carried had to wedge themselves into small open-cockpit planes. For the privilege of enduring such discomfort, approximately 6,000 passengers paid 12 cents a mile fare to the airlines in 1926.

The Government Airmail Line

Up to 1917 neither private American enterprise nor the Government was ready to adopt any system of subsidized commercial air transportation.

A different solution was reached when Congress, now aware of the proved value of the airplane in national defense, granted the Post Office Department an initial approportion of $100,000 for airmail transport in March 1917. As early as 1911, Post Office officials—attracted by the speed of the airplane—had requested such funds.



U. S. Air Force

Army flyers, Colonel Castle and Lt. Proctor, standing by their plane, January 7, 1919, during the Washington to New York aerial mail route mapping tour.

Three-motor I. W. F. "Owl" heavy bomber, 1922. Originally designed for mail service, the plane was converted into a heavy bomber for the Army. It had a maximum speed of 106 MPH and was powered by three Liberty engines.

Scheduled air transportation, or airline flying, in the United States began on 15 May 1918. The Post Office Department, with the help of Army pilots, opened an airmail route between Washington and New York. For one accustomed to the routine matter-of-fact operation of today's airliners, the faltering nature of this early start is hard to imagine. Young nations now struggling to establish similar air services may perhaps take heart from this experience which is described in the following account:

> This service was launched on May 15, 1918, in the presence of President Wilson, cabinet members, and diplomatic dignitaries. Four sacks of mail were loaded aboard the plane, but the engine refused to start for a very simple reason: its fuel tanks were empty. A nearby plane then was drained to provide fuel. The mail plane finally got under way but missed the route to New York and landed on a Maryland farm, 25 miles from Washington. The plane from New York to Washington made a better showing, reaching Washington in 3 hours and 20 minutes. In the first month, only one-third of the scheduled trips between these two cities were completed; flying time averaged 4 hours.[2]

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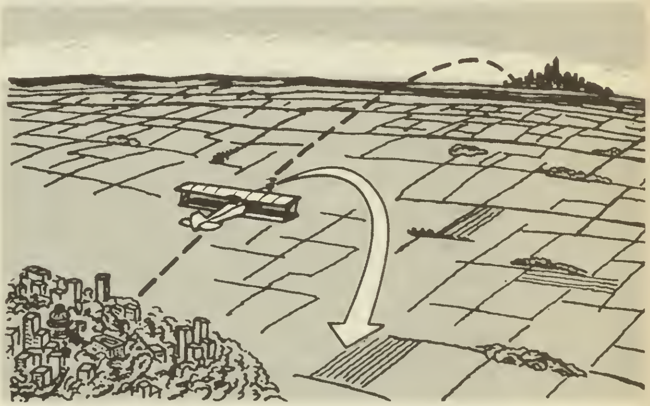
[2] Reprinted from *Air Transportation Management* by J. L. Nicholson by permission of J. Wiley & Sons, Inc. Copyright 1951.

U. S. Air Force Photo

U. S. Air Force Photo

Army Air Service Martin transport, 1922. ▲



President Wilson, Secretary of Navy Josephus Daniels, and the pilot, Major Reyben H. Fleet at the inauguration of the first air mail service, Washington, D. C., May 15, 1918. ▼

U. S. Air Force Photo

This initial airmail service had little commercial value. Though delivery was poor, the cost of a letter was high. Consequently considerable skepticism developed regarding the potentialities of air transport.

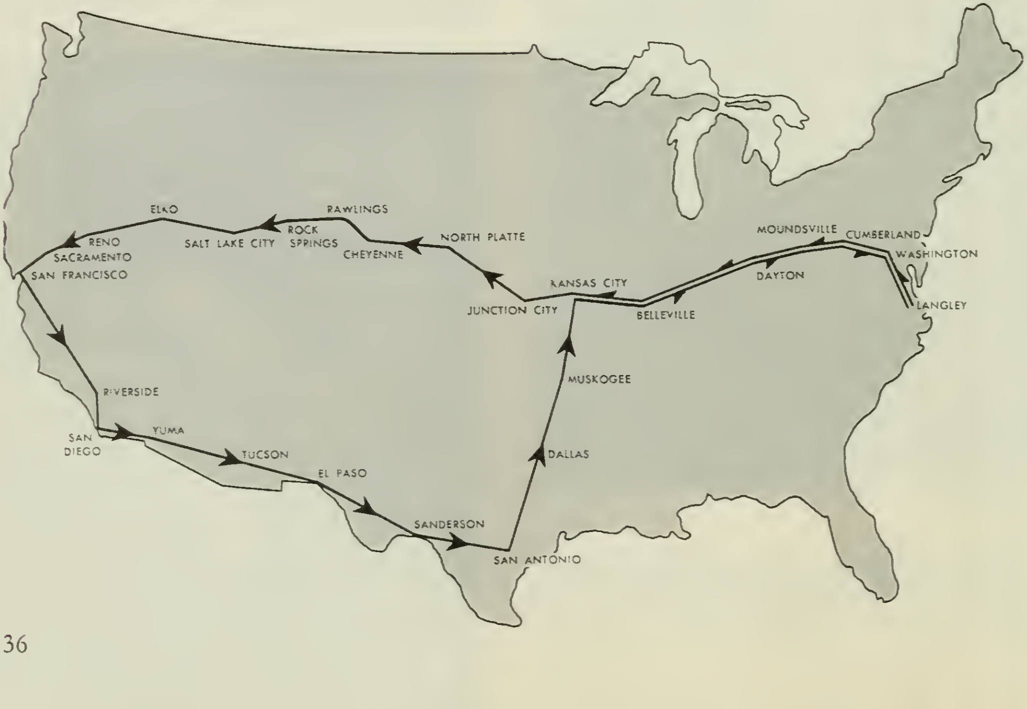
The Federal Government also came under fire for launching an untried air transportation experiment while the nation was engaged in war. It was therefore in the face of much opposition that the Post Office Department continued its pioneering efforts to develop the new medium of travel. Service was begun in 1919 between New York and Chicago and extended to San Francisco during the following year. Although other routes were also opened, it was necessary to abandon them in 1921 in order to concentrate all efforts on the transcontinental service.

In 1922 the Post Office Department undertook the unprecedented step of adapting airplanes and airports for scheduled night flying. It had been apparent for some time that airmail must be flown straight through from coast to coast if it was to compete with the first-class mail on trains. Yet, all over the world, night flying was considered so hazardous for regular operation that European airlines shied away from the problem until the eve of World War II.

By establishing beacon lights along the transcontinental run at 10-mile intervals and constructing emergency landing fields approximately every 30 miles, the Post Office established the world's first lighted airway. On the lighted airway between Chicago and Cheyenne, Wyo., the world's first regular night service was inaugurated on 1 July 1924. Through transcontinental airmail service was soon established with schedules of 34 hours 20 minutes westbound, and 29 hours 15 minutes eastbound. This day-and-night airway from coast to coast became the central trunk of a growing and spreading tree of regional branch lines.

Though day-and-night airway service from coast to coast had moulded regional lines into a national airways system, knotty problems of air transportation still remained to be solved. No substantial progress had been made in two-way radio communication with planes, adequate weather reporting, development of an efficient aircraft, or in methods of coping with bad weather conditions.

Route of round trip transcontinental flight of Martin bomber, October–December 1923.



On this latter point, Thomas Wolfe, an authority on airlines, comments:

> The Post Office officials were particularly disappointed in their failure to develop techniques to meet hazardous weather . . . Stubborn insistence on [an all-weather flying] policy led to mounting pilot fatalities . . . In 1921, there were 12 pilots killed in crashes, and the average life expectancy of the group was not above four years. This condition led the pilots to strike . . . A compromise was reached whereby the station manager, rather than a distant Post Office official, was given final authority to order a flight. Thereafter operations were gradually smoothed out until by 1926 there was only one pilot fatality.[3]

Start of Commercial Airlines

By 1925 the Government considered that its pioneering had progressed to the point where private operation of air transportation appeared practical. Establishment of commercial airlines was urged by aircraft manufacturers, general aviation operators, and Government officials anxious to promote national defense. Despite the many obstacles to commercial aviation, both business and Government supported legislation providing for the carrying of airmail by private contractors on a commercial basis. Under the Kelly Air Mail Act of 1925, airlines were to be paid on a contract basis for carrying the mail. This act and its amendments created an economic basis for a commercial air transport industry.

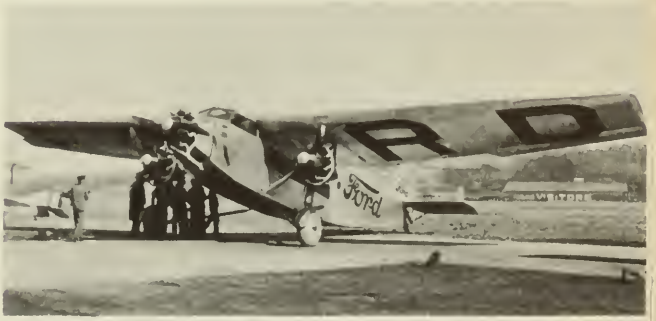
Private capital was readily attracted to the industry and a number of airlines were organized and started operating during the latter 1920's. The Post Office Department, fully aware of the limited capabilities of these newly formed companies, gradually weaned them by awarding "feeder" routes to the New York–San Francisco service. In September 1927 the Post Office turned over the transcontinental route, or "Columbia Line," to private operators, who, except for a brief period in 1934, have flown the mail under Government contract ever since. In effect, this action on the part of the Government amounted to a policy of indirect subsidization.

Moreover, Congress accepted the view that it was a responsibility of the Federal Government to build, maintain, and regulate the airways without which air carriers could not have continued systematic operations. This policy, expressed in the Air Commerce Act of 1926, was consistent with governmental action in the realm of ocean navigation. Responsibility for the airways was given to the Department of Commerce.

Regular commercial air service in the United States actually started early in 1926, when a company organized by Henry Ford began carrying mail on the Detroit–Cleveland–Chicago route. With William B. Stout, a pioneer aviation engineer, as consultant, Ford developed the famous Ford all-metal transport ship built first with one motor and later with three motors. A great improvement over the DeHavilland, the Ford Trimotor became the faithful packhorse of early commercial aviation.

In the first years of private commercial operation, the airlines struggled along with small or no profits, despite the development of large combinations or trusts among airplane, engine, and transport companies. Then suddenly, the airlines, a small five million dollar industry, found themselves riding high on the crest of a wave of airmindedness. This enthusiasm for the air-

U. S. Air Force Photo



Ford trimotor transport, purchased by the U. S. Navy, 1927.

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[3] Reprinted from *Air Transportation* by Thomas Wolfe by permission of McGraw-Hill Book Co. Copyright 1950.

plane was engendered largely by the spectacular transatlantic solo flight of Charles A. Lindbergh in 1927, and heightened by a series of other sensational flights and records. A boom in aviation investments brought 44 scheduled airlines into existence by 1929, and trusts mushroomed into supertrusts. The years 1927 to 1930 saw the greatest expansion in the history of early aviation.

Airmail Routes

By 1926 domestic airmail routes in the United States totaled little more than 2,800 miles. During the first year of operation by private contractors, route mileage tripled and by 1928 exceeded 15,000 miles. Prosperity and the aviation boom of the late twenties pushed route length to 30,000 miles by 1930. Since there was virtually no further expansion until 1938, this was essentially the network of Government airways and commercial airline systems that was to serve the country until the eve of World War II.

Despite concerted efforts by some companies to increase passenger traffic, the airlines depended primarily on airmail revenue. By the winter of 1928 most of the mail-carrying lines were operating planes with closed cabins for at least four passengers. However, passengers were not carried regularly even between New York and Chicago.

U. S. AIRLINE GROWTH, 1926–55

As of Dec. 31	Operators	Aircraft in service	Average available seats [1]	Route mileage operated [2]
1926	13	(1)	(3)	(3)
1927	18	(3)	(3)	(3)
1928	34	268	(3)	(3)
1929	38	442	(3)	(3)
1930	43	497	(3)	30,293
1931	39	490	(3)	30,857
1932	32	456	6.61	28,956
1933	25	418	7.59	28,283
1934	24	423	8.86	28,609
1935	26	363	10.33	29,190
1936	24	280	10.67	29,797
1937	22	291	12.52	32,006
1938	[4] 16	[4] 260	13.91	[4] 34,879
1939	[5] 18	[5] 276	14.66	[5] 36,654
1940	19	369	16.54	42,757
1941	19	370	17.54	45,163
1942	19	186	17.91	41,596
1943	19	204	18.34	42,537
1944	19	288	19.05	47,384
1945	20	421	19.68	[6] 48,516
1946	24	674	25.25	[6] 53,981
1947	28	810	29.93	[6] 62,215
1948	31	878	32.37	[6] 68,702
1949	37	913	35.03	[6] 72,667
1950	38	960	37.47	[6] 77,440
1951	38	981	39.55	[6] 78,913
1952	35	1,078	42.71	[6] 77,894
1953	32	1,139	46.07	[6] 78,384
1954	32	1,175	50.07	[6] 78,294
1955	31	1,212	51.62	[6] 78,992

[1] Obtained by dividing passenger seat miles by revenue miles flown in passenger service.

[2] For the years 1938–48 route mileage operated is a weighted average for the month of December for 1949 and subsequent years the route mileage operated is based on the fourth quarter.

[3] Not available.

[4] Does not include Colonial and Marine Airlines.

[5] Does not include Marine Airlines.

[6] Data subsequent to 1944 based on revised CAB procedures.

Source Operators, average available seats, route mileage: 1926–37–CAA. 1938–55–Office of Carrier Accounts and Statistics, CAB. Aircraft in service, 1926–55–CAA.

Neither the efficiency of the airplane nor the mood of the traveling public had progressed sufficiently for profitable passenger operation. Even the exclusive passenger service operated by Western Air Express, the first of the early contractors to carry passengers, lost the line about $250,000 a year.

Growth of Passenger Traffic

The Wall Street collapse of 1929 brought disaster to many airlines and led to the passage of the McNary-Watres Act of 1930. Under this act the Government encouraged the development of passenger traffic by varying mail payments in accordance with the provision by the airline of increased space and various facilities for passenger safety and comfort. Largely as a result of this legislation, airline passenger accommodations improved materially, and passenger traffic on domestic air routes increased substantially. Other important contributing factors were the renewed aggressiveness of the airlines and the technological improvement of the airplane and the airways. These developments greatly increased both the efficiency and safety of air travel.

With the advent of the Roosevelt administration in 1933, airline control was divorced from aircraft plants, and airline profits were drastically reduced by lowering airmail payments. This governmental policy forced the airlines to turn to passenger and express revenue for their main source of income. Fortunately for the air transportation industry, technological improvement of the airplane had been advancing steadily since 1925 and was on the verge of revolutionizing air economics.

One authority on airline management, Thomas Wolfe, put it this way: "Neither promotion nor government subsidy could create a plane that would fly cheaply. This could be accomplished only by invention. Though this drama was enacted in the laboratories and machine shops, governmental policy was partly responsible. As a result of the Morrow Board Report of 1926, the United States had adopted "an air policy concerned mainly with the development of aircraft as primary vehicles of peaceful commerce." [4] This permitted the thread of technological progress to continue unbroken, albeit with insubstantial appropriations for the air power of a great nation.[5]

Major technical advances made between 1925 and 1936 included the increase of wing loading and the development of multimotor ships, engine nacelles, cantilever wings, and high octane gasoline. The first airplanes to incorporate all these aerodynamic improvements were the Boeing 247 and the Douglas DC–2 and DC–3, which made their appearance as air transports in 1933–36.

With planes such as these, the engineers won the battle of economy. The ton-mile cost, the unit of efficiency commonly employed in air transportation, was slashed by the DC–3 to less than 25 percent of the ton-mile cost of the early DeHavilland. Even the Ford Trimotor was inefficient by comparison.

The equally important progress in the development and expansion of safe airways during the 1930's likewise contributed to the efficiency of air transportation. The Government established more airway facilities, consisting principally of revolving beacon lights, radio range and broadcast stations, weather teletype service, and emergency fields.

By 1934–35 the airway facilities were about adequate for the flight requirements of the period. Between 1929 and 1939 radio broadcasting stations almost tripled in number, radio range beacon stations increased from 9 to 244. Simultaneously, the number of weather stations serving the needs of air transportation jumped sixfold, and the number of lighted airways more than doubled. By 1939 the lighted porportion of airways had increased to 74 percent.

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[4] G. L. Wilson and L. A. Bryan *Air Transportation* (New York, 1949), p. 40.

[5] The Morrow Board recommended that a procurement program should be initiated to develop better equipment. The encouragement to research and development resulting from this policy led eventually to the production of the B–17 Flying Fortress by Boeing and the P–38 by Curtiss.

Safety Factor

However, adequate volume of travel, essential to successful commercial air transportation, still eluded the airlines. Fear of flying continued to keep many people from traveling by air. The general public remained highly sensitive to news of spectacular air crashes. In 1934, for instance, less than half the available airplane seats were filled by revenue passengers, although a record-breaking total of half a million passengers was carried. Unless the new planes flew with loads approximating two-thirds capacity, their potential efficiency could not be realized and costs would remain high.

U. S. Air Force Photo

Lockheed Vega, light transport, 1933.

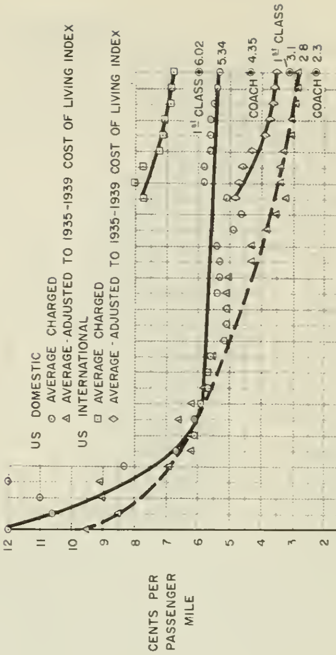
United Airlines Boeing transport in early 1930's.

U. S. Air Force Photo

Douglas DC–1 used by TWA in 1933 as air mail plane.

U. S. Air Force Photo

Success in overcoming fear of flying was directly related to the advance in safety, which now registered steady gains, largely as a result of the introduction of better equipment and improved air facilities. The general trend of the accident curve for air carriers has been steeply downward since 1929. It dropped from an average rate of 26 passenger fatalities per 100 million passenger miles in 1929 to approximately 2 such fatalities per 100 million passenger miles in 1940. Thus, within 15 years of the start of scheduled air operations in 1926, the commercial airlines attained a safety record reached by rail carriers 70 years after the initiation of rail transportation.

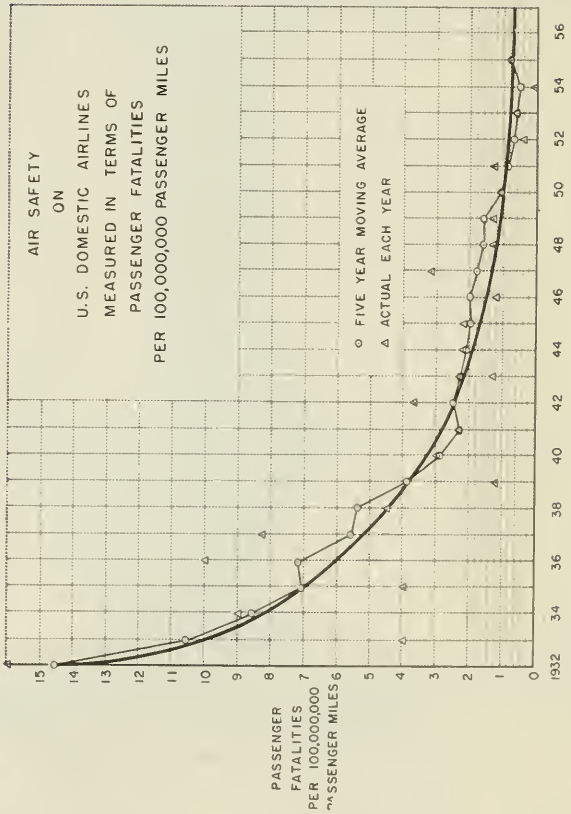


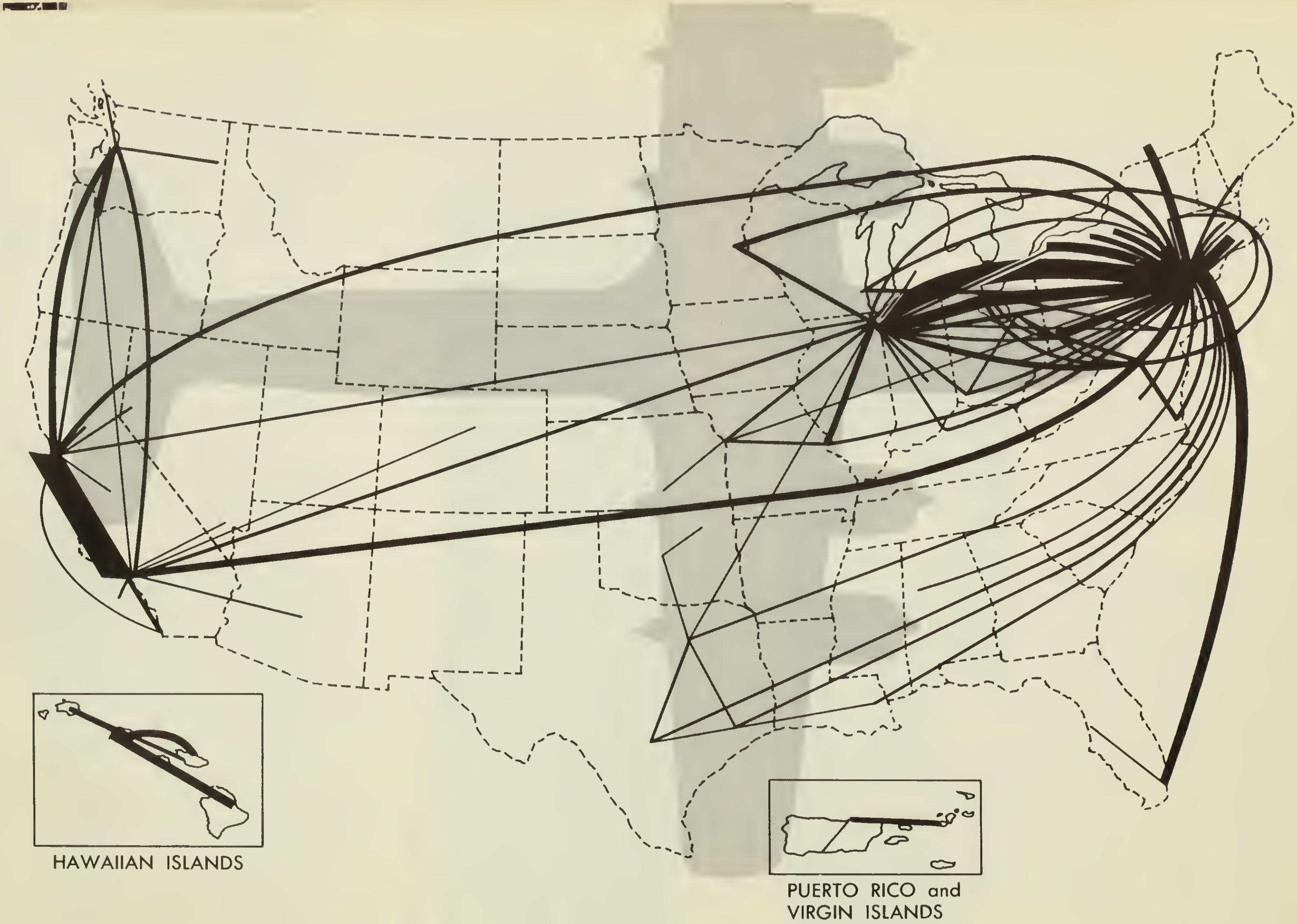
Promotional Activities

Promotional activities of the airlines also contributed to the steady growth of air passenger traffic which now ensued. Freed in 1934 of traditional restraints and forced to scramble for passenger business, the airline managers employed the most up-to-date advertising methods in their promotional publicity and pioneered in means of increasing the attractiveness of airline service. They began to provide passengers with many extra conveniences to make trips more pleasant, furnishing meals, stationery, maps, picture postcards, newspapers, magazines, blankets and first-aid medicines, and help in the care of children.

Reduction in Fares

Reduction in fares now made air transportation competitive with first-class Pullman rail travel. The price per passenger mile in domestic air transport dropped from 12 cents a mile in 1929 to an average of 5.4 cents in 1935 and 5.2 cents in 1938—a level maintained, with some fluctuations, well into the 1950's. This reduction in fares was only partly due to increased efficiency of operation and competition among air carriers; mail contracts also played a role, for they permitted the airlines to distribute the costs of operation over mail service and passenger transport.

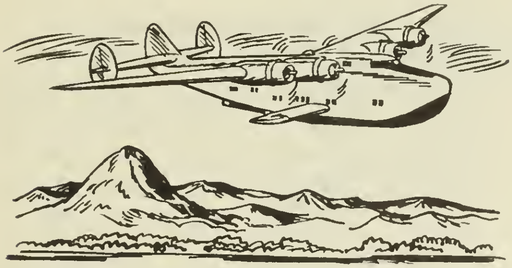




Passenger Traffic Travel between 100 Top-ranking pairs of Airline Stations of the United States, 1948.
(Domestic and territorial traffic.)

Speed and Frequency in Schedule

Fundamental of course in appeal to the traveling public then as now are the advantages of speed and frequency of schedule offered by the airlines in passenger traffic. No other means of transportation has been able to match them in this combination of services. Air transport offered increasingly frequent schedules between the great commercial, industrial, and political centers of activity.



AIRLIFT CAPABILITY OF UNITED STATES CARRIERS ON EVE OF WORLD WAR II

While domestic route mileage stood at 37,500 in 1940, the foreign routes developed and operated by American-flag services totaled 46,000 miles. In 1926 foreign routes operated by United States air carriers consisted of only two short lines covering 152 miles. Major expansion began in 1929 when Pan American Airways opened some 10,000 miles of routes to the West Indies, Central America, the Canal Zone, the entire West Coast of South America, and Buenos Aires. In 1930 further extensions of air service in Latin America almost doubled this route mileage.

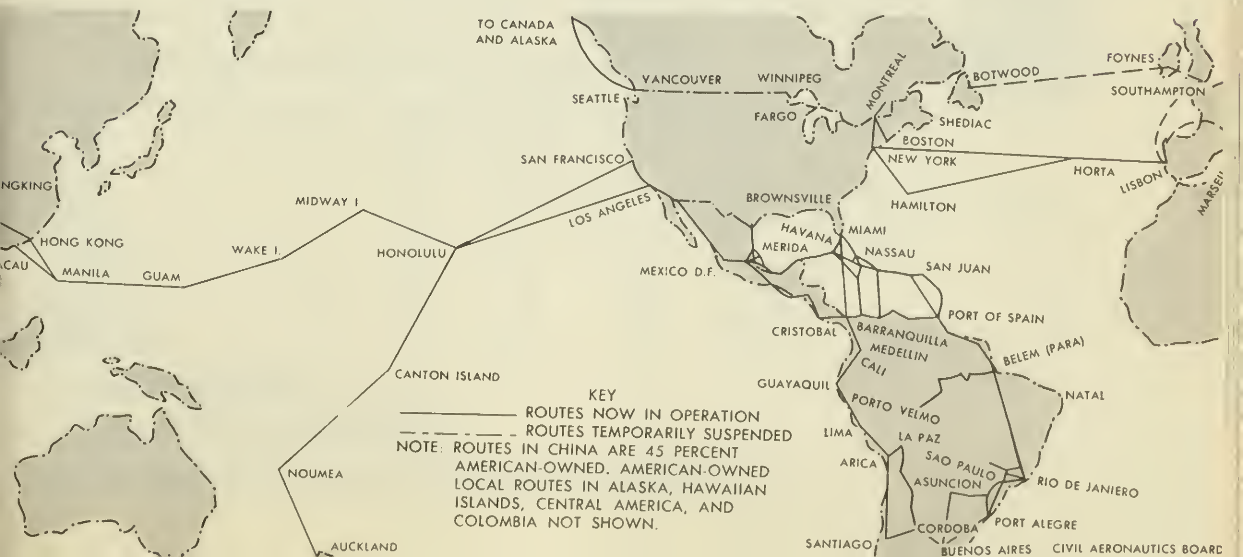
Five years later transpacific air service was initiated by way of Honolulu and Manila, illustrating the importance of political control of key landing areas. This brought total foreign airmail route mileage operated by United States carriers up to 32,800 in 1935. Since then there have been more miles of foreign than of domestic routes.

Between 1935 and 1940 foreign route mileage grew to 46,000 miles. Scheduled transatlantic service was pioneered in 1939 after much preliminary effort. In 1940 new Pacific routes were opened from Seattle to Alaska and from Honolulu across the South Pacific to New Zealand. Thus, in the space of 14 years, the international air transportation system operated by United States carriers grew from a tiny shuttle service to a great network spanning two oceans and linking five continents.

Transportation of Passengers

In 1926 the domestic airlines, which had no regular scheduled air passenger service, carried only some 6,000 passengers along with mail cargo. Just before United States entry into World War II, they transported 2.9 million passengers annually.

Territorial and foreign airline routes of the United States, September 1940.



CIVIL AERONAUTICS BOARD

Revenue passenger miles are a better criterion of growth than the number of passengers, as the latter are reported separately by each carrier and the total therefore includes considerable duplication. A *passenger mile,* as defined by the Civil Aeronautics Board (CAB), is a measure of the volume of traffic representing the equivalent of one passenger transported one mile. Generally, a *passenger mile* means a *revenue passenger mile,* that is, one flown for revenue purposes. Domestic passenger miles increased over 1,000 percent between 1930 and 1941. Passenger miles flown increased from 127.4 million in 1932 to 1,506.3 million in 1941. By 1946 this figure had increased to 6,068.3 million, and by 1953 to 15,337.8 million miles.

As measured by the number of passenger miles flown per mile of route operated, traffic density increased rapidly during the 1930's and by the time of World War II far exceeded that of any other country.

SCHEDULE AIR CARRIER OPERATIONS-DOMESTIC

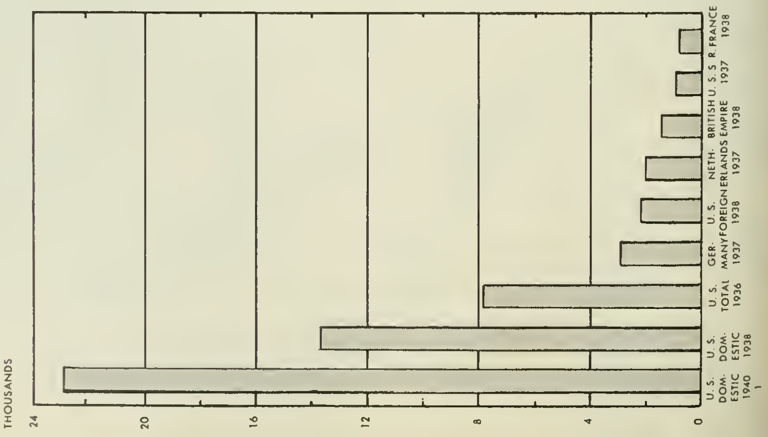
Annual Data-Passenger-Miles Flown, 1932–50 [In thousands]

Year	Total	Revenue [1]	Nonrevenue [1]
1932	127, 433	(2)	(2)
1933	174, 820	(2)	(2)
1934	189, 806	(2)	(2)
1935	316, 336	(2)	(2)
1936	438, 989	(2)	(2)
1937	481, 116	411, 545	69, 571
1938	560, 660	479, 844	80, 816
1939	755, 118	682, 904	72, 214
1940	1, 157, 900	1, 052, 156	105, 744
1941	1, 506, 303	1, 384, 733	121, 570
1942	1, 501, 279	1, 418, 042	83, 237
1943	1, 670, 935	1, 634, 135	36, 800
1944	2, 211, 905	2, 178, 207	33, 698
1945	3, 408, 290	3, 362, 455	45, 835
1946	6, 068, 315	5, 947, 956	120, 359
1947	6, 313, 312	6, 109, 508	203, 804
1948	6, 245, 745	5, 980, 993	264, 752
1949	7, 065, 199	6, 752, 622	312, 577
1950	8, 351, 745	8, 002, 825	348, 920

[1] Not reported separately prior to May 1936. [2] Not available.

Source: 1932–37—CAA. 1938–50—Bureau of Air Operations, CAB.

1 FISCAL YEAR
SOURCE: CIVIL AERONAUTICS AUTHORITY. "EUROPEAN AIR TRANSPORT ON THE EVE OF WAR"
J. P. VAN ZANDT. "JOURNAL OF THE ROYAL AERO SOCIETY," LONDON, SEPT. 1940.

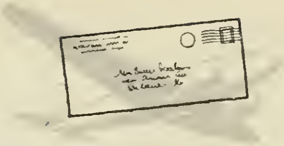


Increased Cargo Carrying Capability

Although the domestic airlines in 1940 carried over four times the mail ton-miles flown in 1930, their dependence on income from mail steadily decreased. Whereas transportation of mail was formerly the chief source of revenue for the airlines, passenger business has contributed since 1935 a larger portion of the revenue. In 1940 mail payments accounted for only 29 percent of the air carriers' revenue as contrasted with 92 percent in 1931. In 1940 payments to air carriers for transporting mail nevertheless amounted to a substantial sum, $18.8 millions. Geographically, airmail and express transport services were far more widespread than passenger traffic, which continued to be concentrated in the industrial section of the East.

In addition to passengers and mail, the scheduled airlines also transported a small volume of express and freight on the eve of World War II.

By 1940 the greatly increased volume of overall business was carried by fewer but more efficient aircraft. The number of planes in service and reserve on domestic scheduled airlines decreased from 497 in 1930 to 358 in 1940. This decrease was offset by the increase in the average number of seats per plane which rose from 6.6 in 1932 to 16.5 in 1940. Aircraft were intensively used in 1940, flying an average of over 300,000 miles on domestic routes. Those on foreign routes flew nearly 11 million revenue miles for an average of 130,000 miles per plane.



Mail Traffic of United States Airlines, 1929–40

[In millions]

Year	Ton-miles, domestic	Pounds, domestic	Pounds, foreign
1929	. . . .	7. 1	0. 7
1930	. . . .	8. 0	0. 5
1931	. . . .	9. 1	0. 5
1932	. . . .	7. 4	0. 5
1933	. . . .	7. 4	0. 2
1934	2. 5	7. 4	0. 2
1935	4. 1	13. 3	0. 3
1936	5. 7	17. 7	0. 3
1937	6. 7	19. 5	0. 4
1938	7. 4	22. 9	0. 5
1939	8. 6	26. 9	0. 7
1940	10. 0	32. 8	1. 0

Source: Civil Aeronautics Administration.

The importance of the vastly augmented airlift capability of the airlines of the United States, with respect both to domestic operations and foreign flying experience, was soon to be demonstrated in the fire and heat of combat. The farsighted policy of Post Office officials like Otto Praeger, who in 1917–18 pushed for the starting and development of United States airmail service, was finally vindicated. Before turning to the role of the airlines in World War II, it is well to summarize briefly the invaluable function performed by the Federal Government in developing our civil aviation capability.

Miles of Express Route and Volume of Airfreight and Express Transported by United States Air Carriers, 1930, 1935 and 1940 [000 omitted]

	Miles of route [1]	Pounds of air express (domestic)	Pounds of air express (foreign and territorial)	Ton-miles of airfreight
930	20	360	109	. . .
935	60	3, 822	1, 743	1, 090
940	94	12, 506	1, 682	3, 469

[1] Domestic, foreign and territorial.

Source: Civil Aeronautics Authority.

GOVERNMENT REGULATION AND PROMOTION OF AIR TRANSPORTATION

Between 1918 and 1926 the Post Office Department pioneered in the development of a civil air network operating on a scheduled basis, using airmail as the basis for getting the air transportation business started. During this period the airlines were owned and operated by the Federal Government.

When the airmail service was turned over to private industry in 1926–27, the function of the Post Office Department became both promotional and regulatory. Through generous mail contracts the department fostered the development of private air transportation companies. Through authority to designate airmail routes, grant route extensions, and determine frequency of schedules, it effectively controlled both the direction and extent of the developing transportation system. For example, in 1930 Postmaster General Walter F. Brown used the powers granted under the McNary-Watres Act relative to the conditional awarding of airmail contracts to promote two new transcontinental runs, each under a separate company. These companies, which ultimately became members of the domestic Big Four, were American Airlines and Trans World Airlines. Along with the Columbia Line, these coast-to-coast services laid down the fundamental route pattern of the country. All were established under the guidance of the Federal Government.

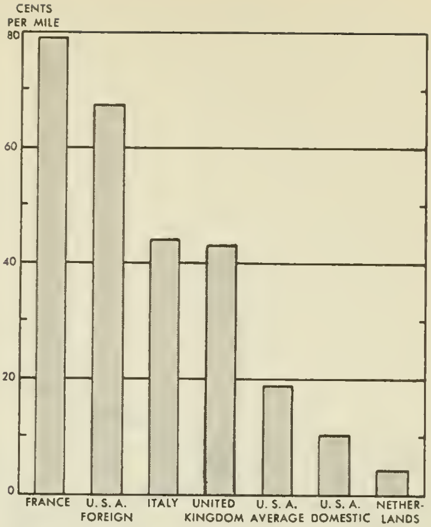
In Europe, air transport had early been recognized as an important instrument of national policy and defense. In the United States, the defense concept of civil aviation, while early recognized and always accepted in principle, has never been as heavily stressed. Upon occasion, such as in the Air Mail Act of 1934, this principle was either ignored or overlooked. Certainly considerations of national defense were largely lacking when in this act Congress proposed to restrict the airmail services of the country to a self-supporting basis.

Fortunately, in 1938 Congress reaffirmed its support of air transportation as an instrument of national policy and defense with the passage of the Civil Aeronautics Act, which remains the basic legislation affecting air transportation to this day. The new act began with a declaration of policy that called for "the encouragement and development of an air transportation system properly adapted to the present and future needs of the foreign and domestic commerce of the United States, of the Postal Service, and of the national defense." Thus the law authorized the development of air transportation to the maximum extent, directing that it assume whatever character and quality the national defense might require.

Moreover, provision of essential air navigation facilities has always been recognized as a public responsibility, both for scheduled and non-scheduled operations, on much the same principle that coastal navigation aids are freely provided for vessels at sea. The Civil Aeronautics Authority is responsible for the construction and maintenance of airways. Federal participation in airport development as a permanent policy was likewise recommended to the Congress by the Civil Aeronautics Authority in 1939, and has become a permanent feature of air and ground facilities development.

On the eve of the Second World War the Federal Government, on the premise of national interest, continued to provide an element of direct aid in its payments to air carriers for the transportation of mail.

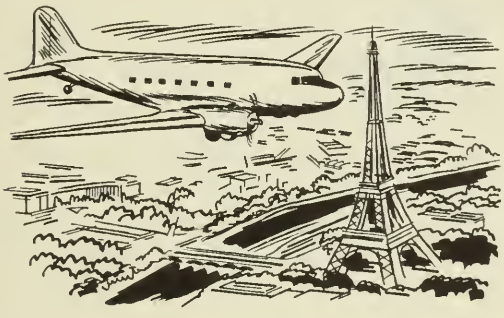
Government payments for mail services include a subsidy only to the extent that the sum paid is in excess of a normal compensation for actual mail services rendered. The fixing of this element of direct aid so as to expedite and not retard the progress of the air transport industry toward an economically sound and stable condition is an important responsibility of the Civil Aeronautics Board, established under the 1938 legislation. The subsidy element in *domestic* airmail payments was on the whole considerably less than the subsidy paid in most other countries. In the case of the United States carriers operating on *overseas* route, the element of direct aid is naturally much higher. The value of this investment became immediately apparent with the outbreak of World War II.



SOURCE: CIVIL AERONAUTICS AUTHORITY

1 U. S. SUBSIDIES OBTAINED BY ARBITRARILY DEDUCTING FROM PAYMENTS TO CARRIERS AS EARNED REVENUE PER-TON MILE DOMESTIC, $100. FOREIGN $150

Air Transport Subsidies per mile flown, United States and principal European Countries, 1938.



SUMMARY OF FOREIGN AIRLINE FLYING ON THE EVE OF WORLD WAR II

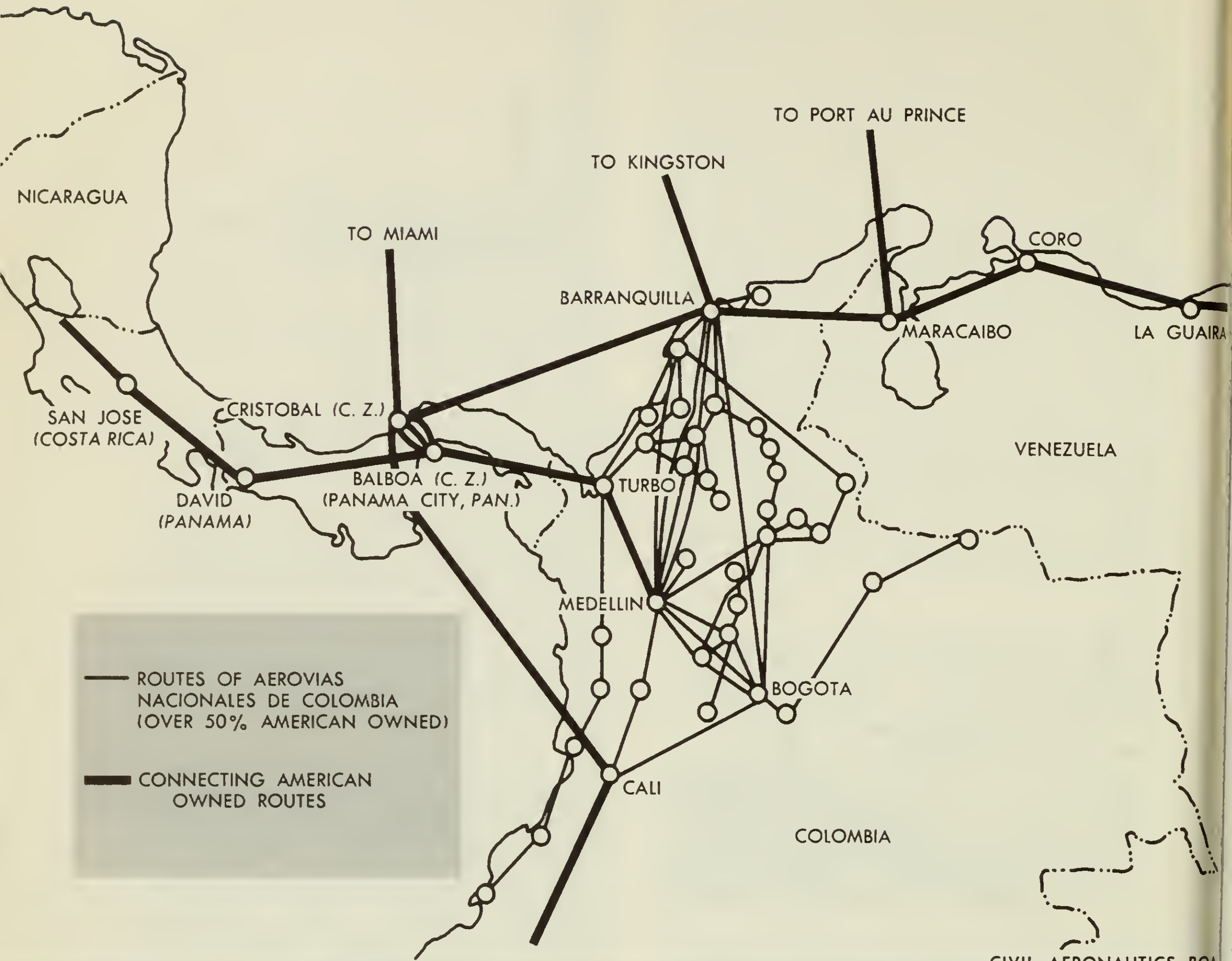
The commercial airlines of the rest of the world also experienced rapid expansion during the interwar period. This growth stemmed both from the inherent advantages of air travel and the stimulation of air transport by many governments, particularly in Europe.

Governmental policy is often reflected in the geographic pattern of a nation's routes, just as in the case of its railroad network. The pattern of railroads in European countries appears on the map in the form of wheels centered on such capitals as Paris, Berlin, and Warsaw with strategic lines radiating outward like spokes. The greater scope of air transportation is reflected both nationally, through the linking of political capitals and key cities within a country, and internationally by the forging of air links with key overseas areas.

The stress placed on strategic territorial and overseas routes has already been seen in the case of the expansion of foreign routes by United States air services. With its partially owned affiliate, Panagra (Pan American-Grace Airways), Pan American Airways also participated in the formation of short-range local airlines in the interior of South America. In addition Pan American pioneered the transpacific route to the Philippines, as well as connections to Alaska.

This strategic emphasis is also evident in the expansion of foreign routes by European air carriers. The United Kingdom's Imperial Airways extended its services toward the dominions and colonies. French airlines, which amalgamated into Air France in 1933, linked metropolitan France with the colonies. The Netherlands, through its national airline, *KLM,* concentrated on the East Indies service. Germany's *Deutsche Lufthansa,* without colonies to stimulate its overseas development, devoted much attention to South America, where some German-controlled airlines were established. In the

ROUTES OF AEROVIAS NACIONALES DE COLOMBIA (AVIANCA) SEPTEMBER, 1940



CIVIL AERONAUTICS BOA

U. S. S. R. the same strategic impulse was manifested in the expansion of Soviet air routes to outlying regions of the Siberian Arctic, Central Asia, and the Soviet Far East.

The period from 1934 to 1939 was marked by the development of airport and navigation facilities along the major air routes of the world. At the same time the use of more efficient aircraft permitted route mileage to double, miles flown to triple, and the number of revenue passenger miles to increase in even greater proportion. With the closing of the North Atlantic gap by Pan American and British Imperial Airways in the summer of 1939, it became possible for the first time to fly around the world on scheduled airlines. Of the 300 million aircraft miles[6] flown a year by the world's scheduled airlines in 1939, nearly one-half (146.2 million) were flown by United States domestic and international carriers.[7]

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[6] An *aircraft mile* is a measure of the volume of air traffic representing the equivalent of the flight of one aircraft over a distance of one mile.

AIR TRANSPORT IN WORLD WAR II

When war broke out in 1939 the transport of passengers and freight by air, although growing rapidly in importance, still constituted only a relatively minor portion of international transport. The only exception was in those parts of the world where rugged terrain and climatic extremes made it uneconomical to develop much surface transportation, as in Colombia and Alaska. Except in such regions, relatively little freight was carried by air throughout the world. A major obstacle to civilan expansion was the lack of adequate ground facilities for air operations in many parts of the world.[8]

However, the military pressure of a world at war compressed decades of normal peacetime aviation development into a few years. Military urgency provided the impetus necessary to promote international air transportation from a minor to a major component of the world's transportation system. Of course many of the cargoes flown by air during the war would have been carried by surface transport in time of peace. The logistics of war, calling for speed, placed little stress upon economy of operation.

International Air Transport Operations

How the air transport picture changed quickly and drastically under the exigencies of war has been well described by the ICAO:

Huge military air transport organizations were built up on the bases of existing peacetime international services. The Royal Air Force Transport Command, which took over a small civilian flying organization ferrying aircraft from North American factories to the United Kingdom, expanded into a worldwide network which carried passengers and freight to all military theatres. In six years of war Transport Command ferried 27,000 aircraft from North America to the various combat areas; in just one month alone, its aircraft flew nearly 5,000,000 miles, carrying 21,000 passengers and 23,000 tons of freight. Similarly, the Army Air Transport Command and the Navy Air Transport Service became major ingredients in the recipe of United States military power. They blazed a trail of air routes and landing fields around the world; Air Transport Command routes alone covered 200,000 miles, along which 2,800 aircraft flew more than 600,000,000 passenger miles per month. Much of the success of these transport services was due to the civil air transporting personnel . . . [furnished] to the military forces."[9]

World War II Douglas C–54 transport.

World War II Curtiss C–46 Commando transport.

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[7] International Civil Aviation Organization (ICAO), *Memorandum on ICAO: The Story of the International Civil Aviation Organization* (Montreal, 1951); ICAO, *Digest of Statistics Nr 60* (Montreal, 1957), p. 103.

[8] ICAO, *Memorandum on ICAO*, p. 10.

[9] Ibid.

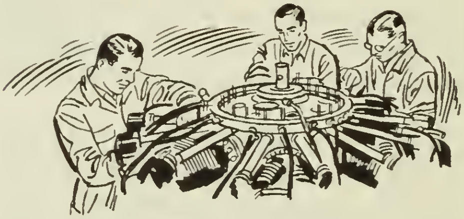
Contributions of United States Civil Aviation to the War Effort (1941–1945)

The airlines and general aviation made significant contributions to the successful prosecution of the war in which the nation found itself engaged on 7 December 1941. While those of general aviation were of a largely general aeronautical nature, except for the civilian pilot training program and the Civil Air Patrol, those of the airlines were on the whole more direct and immediate in their effect on the waging of the war, especially in the critical early days when our military air power existed largely on paper. Among the tasks performed by the airlines during World War II, the most important are described below:

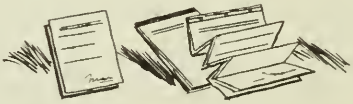
1. Provided the Armed Forces with Transport Aircraft. At the outbreak of war the airlines turned over 324 aircraft, or half their domestic fleet, to the military forces. These commercial airliners formed the nucleus around which the Army Air Forces and Navy were able to build their huge transport commands. In addition the airlines also delivered to the armed forces airplanes previously ordered for commercial use. Some of these planes were transferred even before Pearl Harbor.

Perhaps just as important to the successful prosecution of the war was the healthy condition of the airline business at the outbreak of the war. Had the United States lacked sound, thriving, and expanding commercial airlines, the aircraft industry would not have been so technologically advanced or economically important. Even with this commercial stimulus, aircraft production was inadequate for the immense military needs, and it was not until several years later (March 1944) that the required top production level was reached.

2. Supplied Key Personnel. In addition to supplying the armed forces with aircraft, the airlines furnished the services with many experienced executive personnel to set up and operate the transport commands. These executives became commanding generals, deputy commanders, chiefs of staff, etc. Without these top men, the gigantic wartime airlift operations described above would not have been achieved at so early a date.



3. Supplied Many Technical Services. When the war broke out, the airlines were the principal source of maintenance and repair personnel. The military services turned to these technicians for servicing, maintaining, converting, and modifying their aircraft. They worked in both airline-operated and Government-controlled repair shops.



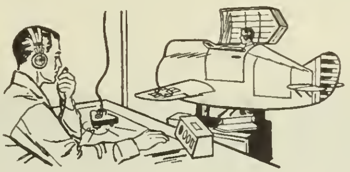
4. Furnished Contract Flying Service. As stated earlier, the armed forces were not able to perform all the flying functions demanded by the war effort. The airlines filled the gap by supplying contract flying service to ATC and NATS. These contract flying operations grew remarkably between 1942 and 1945.

Total Contract Operations of the Airline with ATC and MATS

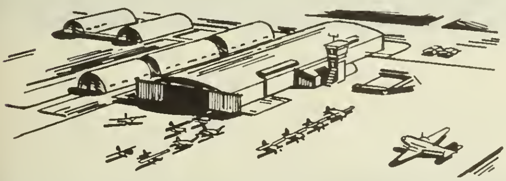
[000 Omitted]

	1942	1943	1944	1945
Passenger-miles	327, 400	761, 200	1, 259, 000	1, 783, 500
Ton-miles	118, 300	247, 900	355, 800	420, 800
Plane-miles	65, 800	95, 000	121, 100	107, 300
Hours flown	407	593	707	579

Source: Reginald M. Cleveland, *Air Transport at War* (New York, 1946), p. 316.



5. Trained Flying Personnel. The airlines also helped the war effort by training navigators, pilots, mechanics, and meteorologists for ATC and NATS. In addition, private operators expanded their facilities, and trained thousands of fliers under the Civil Aeronautics Administration's Civilian Pilot Training Program. Together, these students became the backbone of the Army, Navy, and Marine air arms.



6. Provided Airbase Facilities. Civil authorities in conjunction with CAA established airbase facilities for the use of both scheduled and non-scheduled airlines in cities throughout the United States. These formed the nucleus for many military installations when expansion of such aviation facilities became vital to national defense.

7. Met Demands of Accelerated War Business. Despite the tremendous inroads made into the civil air transport fleet, the airlines greatly speeded up the conduct of war business through commercial airline travel. Notwithstanding a forced cut of nearly half in daily scheduled plane miles, the airlines in 1942 were able to carry 82 percent of the last prewar year's number of passengers. In 1944, with less than two-thirds the transports operated in 1941, the airlines carried approximately 15 percent more passengers. Though limited to strictly domestic scheduled operations, this feat was made possible by pushing up average aircraft use from a prewar average of 6.5 hours to 11.5 hours a day in the summer of 1944. With a load factor of over 90 percent, it became necessary to establish a system of priorities for air passengers and express. Recognition of the importance of this service and the availability of new aircraft enabled the military to return 112 aircraft to the airlines in 1944.

One of the most significant developments in domestic air cargo transportation was the vastly increased use of air express. Air express pound-miles jumped fivefold and by 1944 made up 5 percent or more of total airline revenue This volume was indicative of the potentialities of postwar cargo service In 1944 the airlines operated 14 domestic cargo routes for the services in the United States. Eight airlines did contract flying to war theaters for the armed forces.

Effects of War on Civil Aviation

The tremendous wartime advances made in the development of aircraft and engines during World War I had a direct and beneficial effect on civil aviation. Later, however, benefits flowed the other way. The

▲

Douglas C–47 Transport.

Boeing Clipper.

▼

Lockheed C–121 Constellation.

▼

Boeing B–17's.

technological development of civil aviation in the 1930's provided much of the basis for the rise of military transport aviation in World War II. During that decade the continued growth of the airlines and general aviation flying (along with small military appropriations) nurtured the aircraft industry and technological research and was largely responsible for the extensive development of airways and ground air navigation aids. With the coming of the war, Boeing Clippers, Consolidated seaplanes, and DC–3's were pressed into military transport service, along with B–17 and B–24 bombers, to relieve the critical shortage of vitally needed air transportation equipment. Production was speeded on the prototypes of the Douglas DC–4 and the Lockheed Constellation, which had been flown before December 1941.

Then during World War II came unparalleled scientific and technological progress, which in turn profoundly affected civil aviation. Effects of those advances will continue to be felt for many years. Most significant, though not of immediate importance, was the revolutionary breakthrough effected by German inventive and technical genius in 1944 with the large-scale production and operational use of jet-propelled and rocket fighters and of guided missiles. This development was particularly significant because of the limitations of horsepower output and propeller top speeds in conventional aircraft. Wartime manufacture and operational use of jet-propelled aircraft foreshadowed the coming of a revolutionary new era in air transportation within a matter of years. These and other scientific and technological developments—notably radar—made possible much of the postwar expansion of civil aviation through improvement of equipment and airways.

A more immediate effect of the war, however, was the over-optimism generated by the achievements of wartime air transportation and the tremendous demand for travel on the airlines. These factors contributed appreciably to the expansion of the airlines and helped create the great aviation crisis of 1947 in the United States.

Consolidated B–24 Liberator.

POSTWAR CIVIL AVIATION IN THE UNITED STATES

As the war drew to a close, the airlines, already carrying a record volume of passenger and freight traffic, found themselves swamped by a big demand for air travel. Part of this demand undoubtedly was due to reduction in fares at a time when prices in general were beginning to rise. The basic passenger fare had just been reduced to 4.5 cents a mile and mail pay had dropped to 45 cents a ton-mile. These reductions were part of a compromise arrangement which followed a Civil Aeronautics Board order for a hearing on reducing the mail pay of the four largest lines from 60 to 32 cents a ton-mile.

Demobilization of millions of service personnel swelled the heavy volume of airplane travel. Reconversion of industry to a peacetime footing was also responsible for part of the demand. The pent-up desire of people to travel contributed further.

Both Government officials and airline executives were misled by the heavy demand for air travel and based their plans on a peacetime continuation of this patronage. Already large orders for new equipment were further increased, and projected route expansion assumed feverish proportions.

With the phasing out of the war, the airlines launched an ambitious program of route expansion. At the same time, new or established carriers filed hundreds of applications for feeder routes with the Civil Aeronautics Board. For one carrier to protect its territory against the invasion of another, it had to apply for still more routes as a defensive measure. The routes applied for at one time reached a fantastic total mileage more than double the railroad trackage of the country.

Meanwhile, the release of thousands of trained military aviation personnel brought many pilots into the irregular carrier field (general aviation). This influx of personnel, along with the disposal of surplus transport-type aircraft, provided the basis for a spectacular development of non-scheduled cargo and passenger operations. By September 1944 approximately 500 non-scheduled carriers were registered with the Civil Aeronautics Board. Previously, irregular carriers such as these had been exempt from CAB economic regulation. Soon after the war their competition, based largely on the surging demand for cargo and travel service, became important enough to warrant regulation.

The Aviation Crisis of 1946–47

Expanding their operations to meet the rising demand, the scheduled domestic airlines of the United States in 1946 increased their passenger revenues by 65 percent and their express-freight revenues by 30 percent.

In spite of the gains in business they showed a net loss of $7.2 million during 1946, compared with a profit of $17 million in 1945. Only 8 of the 20 carriers reported net profits. One line came precariously close to bankruptcy, while others suffered losses running well into the millions. Although mail income had dropped by over one-third, operating revenues of the industry had risen almost 50 percent. This gain was offset however by a rise in operating expenses of almost 80 percent. The situation became so serious in 1947 that a crisis developed in American aviation.

The airline industry had to cancel much of the equipment it had on order and began to use up its cash reserves and credit. In the aircraft industry it became evident that for reasons of cost no new super air transport could be produced beyond those designs completed in 1947. The Air Force itself depended principally on aircraft left over from World War II. Nationwide, the production rate of new equipment dropped even below the obsolescence rate of military and commercial planes. Through loss of jobs highly skilled engineers and other technical people were forced to leave the aircraft industry. In the air transportation field many also found the going difficult.

In short, both the aircraft industry and the airlines were threatened with collapse, a condition which would have had disastrous effects on military aviation. In the year ending 30 June 1947 the net losses of the airline industry mounted to critical proportions.

The President's Air Policy Commission

To meet the crisis President Truman in July 1947 created the temporary Air Policy Commission to make an objective inquiry into national aviation policies and problems, and to assist in formulating an integrated national aviation policy.

At the same time a Congressional board was appointed for a similar purpose: to insure insofar as possible the formulation of complete, unbiased, and independent reports on the status of national aviation and its requirements. It is significant that the two final reports were virtually identical in their observations and major conclusions.

The report of the President's Air Policy Commission, entitled *Survival in the Air Age,* is a document of major importance in the history of American air power. This 1948 report, along with the Congressional report, *National Aviation Policy,* established the framework for a new national security policy based on air power.

The civil aviation section of the report takes up 30 pages and discusses the major problems facing the airlines and the Government. The findings and recommendations of the President's Air Policy Commission in regard to airline flying are summarized as follows:

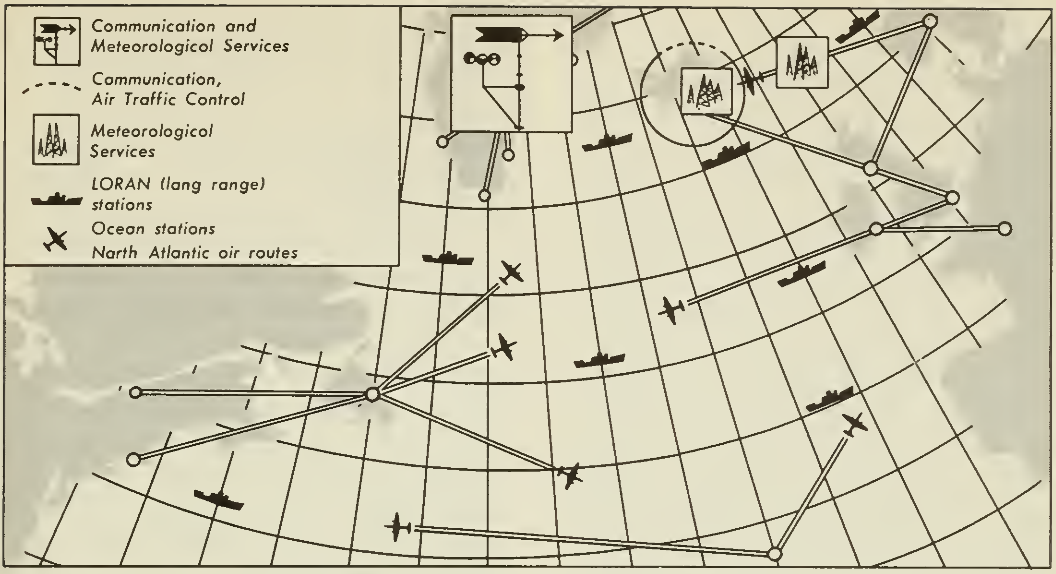
A. Subsidization

1. The airlines, the most important element of civil aviation, are passing through one of the most serious crises in their history.
2. The crisis is significant for two reasons:

   a. It will, if not arrested, contribute to rapid deterioration of airline service to the public.
   b. Of even greater importance, it will threaten the existence of the airline fleet, which is "of great value to the military services as a reserve in time of war."
3. The airlines, as a potential military auxiliary, must be made strong and healthy once more.
4. The difficulties of the airlines are attributable primarily to over-expansion based on mistaken assumptions about postwar traffic.
5. The over-all situation of the airlines is the same as the prewar situation in that "the revenue from passengers and cargo, plus a revenue for the carrying of the mail roughly equal to the passenger rate, would not support the operations of many of the airline companies."
6. If the airlines are to continue in operation and resume their interrupted progress toward self-sufficiency the government will have to increase the mail rates.
7. The Civil Aeronautics Board (CAB) will have to act quickly both in determining new airmail rates and in granting enough immediate mail pay to keep all the lines in business to the extent required by the national interest.

B. *Safety, Regularity, and Improvement of Airlines and Airways*

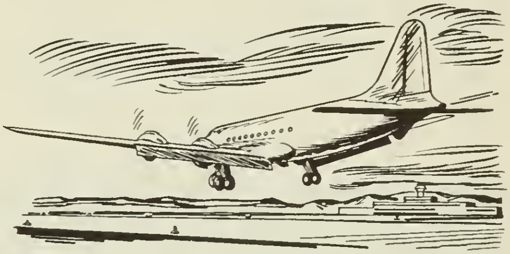
1. The question of safety in commercial aviation is of prime importance because of its psychological effect on traffic and therefore on the prosperity and self-sufficiency of the airlines.
2. New types of transport planes being introduced into airline service should be put through longer test periods under operating conditions approximating those under which they will later be flown commercially.
3. The lack of consideration for safety shown by some contract [irregular] carriers reveals the need for regulatory economic control over their operations by the CAB.
4. An increase in regularity of service on the airlines is second only to the safety problem.
5. A greatly improved nationwide system of air traffic control, navigation, and landing aids is a top priority for civil air transportation as a basic condition for realization of greater safety and regularity on the airlines.
6. It is equally important to expedite research and development programs in the field of electronic aids to aviation, in order to insure that the means of handling traffic will keep pace with its steady increase.
7. Larger Government expenditures for electronic aids to air traffic control, navigation, and landing will do more than anything else foreseeable to build the airlines toward economic self-sufficiency.
8. Such expenditures will materially bolster certain phases of the national defense.
9. The airlines themselves can improve their operations to make air travel more attractive to the public through greater safety and regularity of operation; in the past they have lost estimated millions of dollars because of flight cancellations and irregularity in general.
10. Congestion of traffic at airports sometimes causes delays in aircraft arrival even in good weather; local governmental action can and must remedy the basic situation, with the assistance of the Federal


Communication and Meteorological Services
Communication, Air Traffic Control
Meteorological Services
LORAN (long range) stations
Ocean stations
North Atlantic air routes

Air transport services in the North Atlantic, 1956.

Government under the Airport Act.[10]

11. Aviation communications and electronic aids are in very unsatisfactory condition on most of the international routes flown by United States carriers; the "joint support" program of ICAO[11] provides the best and fairest means of insuring the installation of adequate aviation aids along the air routes of the world.



ERA OF RECOVERY AND EXPANSION

The airlines and the Government now cooperated to carry out the basic reforms and improvements recommended in the reports of the President's Air Policy Commission and the Congressional Aviation Policy Board. Both the Government and industry marshalled their resources to concentrate on safety as their primary objective. Unprecedented progress was made in the installation of radio aids such as ILS (Instrument Landing System), VHF (Very High Frequency) radio signal stations, radar devices, and high intensity approach lighting facilities.

In spite of these improvements, financial losses for the airline industry as a whole continued through 1947, 1948, and into 1949. Operating expenses remained higher than revenues. The reassertion of competition meant higher advertising and sales ex-

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[10] The Federal Airport Act of 1946 authorized financial grants totaling $500 million within the United States over a 7-year period and an additional $20 million for Hawaii, Puerto Rico, and Alaska. Local and State expenditures for airport construction are supplemented by such Federal funds.

[11] The International Civil Aviation Organization (ICAO) grew out of the international civil aviation conference held in Chicago in 1944 and was established provisionally the followng year with headquarters in Canada. Formal establishment came in 1947. The basis for this international governmental organization is the convention on international civil aviation (Chicago, 1944). The objectives of the organization are to develop the principles and techniques of international air navigation and to foster the planning and development of international air transport. ICAO is an affiliate of the United Nations.

penditures. The continuing spiral of general prices resulted in increased labor and material costs. The advent of long term financing with resultant debt charges also tended to keep earnings down. The CAB believed a partial solution of the financial difficulties lay in the merger of specific airlines and permitted some companies to sell segments of their routes to other lines. Through approval of interchange-of-equipment arrangements between airlines, the CAB also encouraged more economical use of equipment over certain routes which did not generate sufficient business to warrant competition between two carriers.[12] In addition to granting higher temporary mail pay rates, the CAB also approved some loans made to the airline industry by banks, insurance companies, and the Reconstruction Finance Corporation.

Offsetting some of the operating problems which continued to plague the airlines were notable additions to airline transport aircraft. Among these were the DC–4, DC–6, Constellation, and Stratocruiser types. These modern four-engined aircraft usually carry about 50 passengers at speeds up to 300 mph. Smaller but very efficient two-engined types were the Convair 240 and the Martin 2–0–2, which carried approximately the same load as the older DC–2 and DC–3 at speeds of better than 200 mph. Comparative operating costs and distribution of these and later aircraft among the airlines follow.

By employing newer and more thoroughly tested equipment and taking advantage of the improved airways, the airlines were able to increase the safety and regularity of their service. The year 1950 saw the domestic airline industry achieving an unprecedented safety record. The passenger fatality rate was only 1.1 per 100 million passenger miles flown.

Airline passenger business showed a marked upturn in 1949, and by the latter part of the year the industry was out of the red. In 1950 the industry experienced its most successful year; with all categories of traffic at record-breaking levels for two years in a row, the industry's profits were the greatest since the end of World War II. Domestic air carrier operating revenues exceeded the half-billion dollar mark for the first time, giving the airlines a net profit of $63 millions. About half of this profit would not have been possible without $30 millions of mail subsidy.

Continued Improvement and Expansion, 1950–1957

The equipment of the airlines and the airways over which they flew continued to improve during the ensuing years. By 1952 the Government was able to announce the opening for use of 46,000 miles of new "Victor" airways. These new airways, superimposed upon the existing low-frequency ones, are equipped with very high frequency (VHF) omnidirectional ranges (VOR). The advantage of the new airways system is that it can be tuned in from any direction and provides guidance to aircraft off as well as on the 10-mile wide airways. In contrast the low frequency system offers bearings in only four directions and is vulnerable to signal interference in bad weather. Progress continued in the installation of instrument landing systems (ILS) and ground-controlled approach systems (GCA).

To meet the pilots' need for distance-measuring data to complement the bearing or directional information received from the VHF radio ranges, the electronics industry developed and produced new distance-measuring equipment (DME). Installation and operation of DME provides invaluable navigational help to all pilots and speeds up the increasingly complicated tasks of the CAA air traffic controllers.

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[12] Interchange-of-equipment agreements between two companies permit one plane to fly on through a connecting terminal at which the respective companies install their crews. In the foreign carrier field such arrangements make it possible for a Panagra plane flying up the west coast of South America to land in Panama where Pan American charters the plane and flies it on to the United States. This process is reversed on the return trip.

With the expansion of civil and military aviation there has been a tremendous increase in the volume of air traffic control operations. Traffic controllers are able to handle the increase by making more and more use of the newly installed radio and radar instrument approach systems.

Under CAA traffic control an airplane lands or takes off somewhere in the United States every one and one-half seconds. In 1956 CAA had 42 traffic towers each of which controlled more than 100,000 landings and take-offs per year. Abroad there was only one tower in this category—at London, England. CAA's 8,000 traffic controllers also handled more than 10,000 instrument flights daily and under their control military aircraft made 9 million position reports each year.

All air and naval commands depend upon CAA traffic service every time they send a plane into the controlled United States air space. The CAA Administrator reported in 1956 that the military demand for CAA assistance had become so great that the CAA had had to open a Central Altitude Reservation Facility in Kansas City to care for military requests from all over the United States. He estimated that one-third of all traffic control tower operations were devoted to servicing aircraft of the general aviation fleet, which flew three times as many hours as the airline fleet. And he announced that CAA towers, which were responsible for providing safe and speedy traffic control service to some 38 million domestic airline passengers in 1955, were preparing to handle 93 million in 1965.[13]

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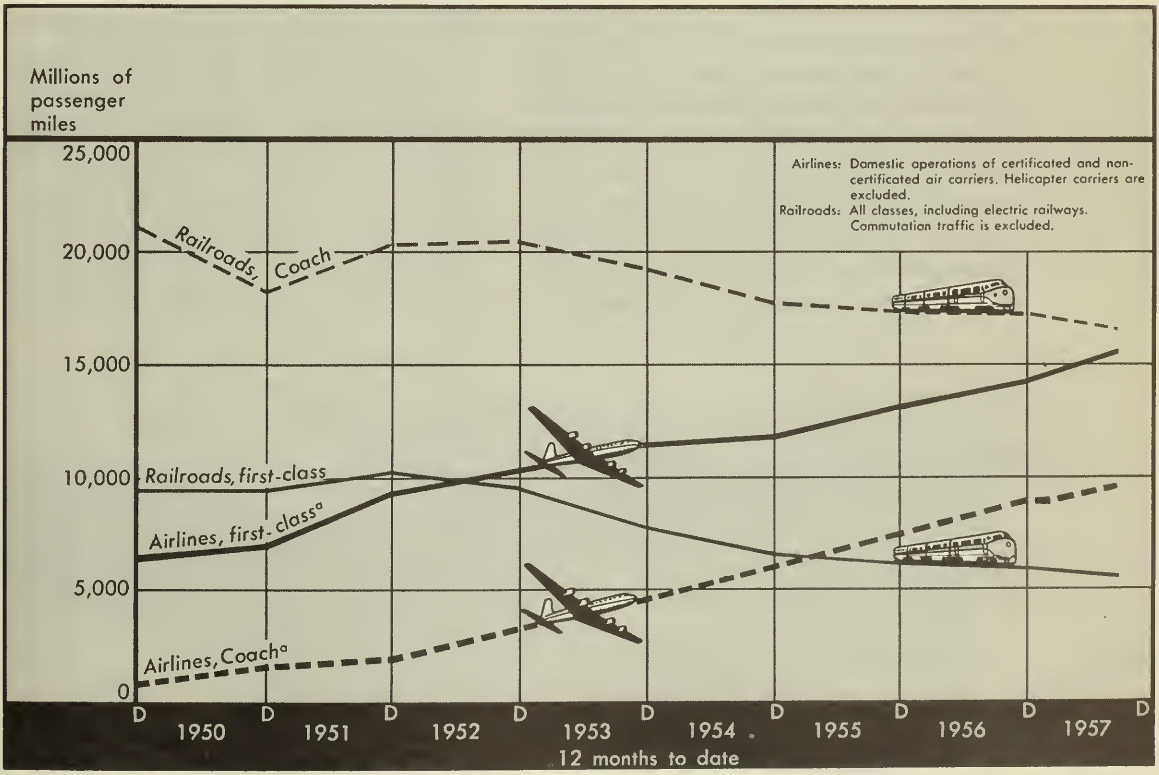
[13] James T. Pyle, "CAA and Air Traffic Control", *U. S. Air Services,* Vol. 41 (August, 1956), pp. 17–19.

Comparison of air and rail revenue passenger-miles.



^a Excludes nonscheduled service of certificated air carriers (negligible in amount), which cannot be identified as being either first-class or coach.

The role of the CAA-controlled airways would rapidly become critical in the event of a national emergency. If the United States were in imminent danger of attack, the airways system would almost certainly be placed under military authority. As far back as the Korean War, both CAA and the Air Force were studying plans to transfer the airways to the Department of Defense for the duration of a national emergency.

So great was the expansion of the airlines during this period that by 1956 any one of the Big Four lines was larger than the entire industry had been ten years earlier. Shooting past the Pullman trains for the first time in 1951, the airlines by 1955 had reversed the 1946 Pullman–airline ratio of traffic completely—three out of every four long distance passengers had shifted from Pullman to airline service. Between 1938 and 1955 the number of airlines certified to operate over specific routes increased from 22 to 59; aircraft in service rose from 345 to 1,454; and total airline payrolls climbed from $27 million to $526 million.

Measured in terms of 1939 business, the airlines far outdistanced other rapidly growing industries. Air travel had a 30-fold increase, compared with a 15-fold increase for plastics, 10-fold for aluminum, and 8-fold for chemicals. With United States international airlines hauling over 3.5 million passengers a year, more than 70 percent of all United States overseas travel moved by air. Air travel had become a mass medium of transportation.

Yet in a period of rising prices the cost of an airline ticket in the United States rose only 3.7 percent between 1939 and 1955. Such economy was made possible by the continual addition of new and improved equipment. With few exceptions, the new airliners introduced since World War II have been bigger, faster, and cheaper to operate than their predecessors.

Outstanding additions to the airline fleet during the postwar years were the DC–7 and the British Viscount. The Viscount was the first turboprop transport to serve on United States airlines. The Lockheed Electra became the first United States-built commercial turboprop aircraft. Airline companies will spend an estimated $3 billion for new jet and piston-driven airliners during the decade 1956-1965.

With the introduction and more extensive testing of newer and more efficient aircraft, the airlines have been able to make perhaps their greatest appeal to a mass market: safety. Through improvement of Federal airways controlled by CAA, the airlines achieved a new safety record in 1954—0.09 fatalities per 100 million passenger-miles flown.

A very important result of the expansion during the record period of prosperity was the fact that the 12 great trunk airlines had freed themselves entirely of Government subsidy by 1957. On the other hand, the local service or feeder airlines were dogged by economic woes despite increased levels of operation and continued to require subsidies.

Increased Airlift Capability: Military Potential

Expressive of the remarkable growth of the scheduled air transportation industry is its increased airlift capacity. For example, between the hours of 5:00 P. M. and 6:00 P. M. during the summer months of 1955 the airlines had 665 planes in the air carrying approximately 25,000 passengers and 665,000 pounds of cargo including mail, freight, and express.[14] Figures from the February 1957 issue of *Interavia* clearly show the extent of projected increases. The entire domestic scheduled airline fleet at the end of 1955 theoretically was capable of handling cargoes of 3.1 million ton-miles per hour. This figure compared favorably with a total of 4.2 million ton-miles per hour that theoretically could be developed by the combined civil air fleets of the United States, Canada, the United Kingdom, and Western Europe.

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[14] Aircraft Industries Association of America, *Aviation Facts and Figures* (Washington, 1956), p. 50.

With the incorporation by 1960–1962 of the 250 Boeing 707's and DC–8's ordered in these four areas, this transport capacity will be augmented by 17.2 million ton-miles daily. Of this increase, the United States and Canada alone will produce 13.5 million ton-miles.

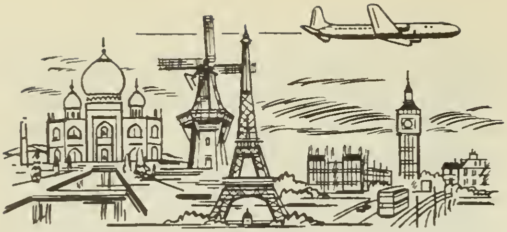
According to *Interavia's* estimate, this projected transport potential in terms of combat troop movement (with light arms) means that the combined North American and European fleet of 1960–1962 could carry approximately 27,000 men across the Atlantic within 24 to 36 hours. This is the numerical equivalent of three light divisions. The *Interavia* article goes on to say: "If a fleet of 100 to 150 heavy cargo aircraft, of the category of those under test in the United States, were added to the civil fleets, the inter-Allied Command could transport the equivalent of three full-equipped light divisions or their atomic equipment over a distance of 3,000 to 3,500 miles." It can hardly be doubted that this future capacity could materially modify world strategy and politics.

If the military services were to allocate or charter heavy all-cargo aircraft to the civil airlines (scheduled and irregular), the basis for a revolutionary expansion of the air freight business of the United States would be laid. It is not irrelevant to note that the all-cargo lines need ships of this type if they are to make sizeable gains in volume. Operating costs for the giant C–132 shown below are estimated to be approximately 3.5 cents a ton-mile, only a fraction of current operating costs in European air transport. The United States Navy recently set a precedent in domestic air transport by chartering a DC–6A cargo aircraft to a civil airline. Other lines have petitioned for similar charters. If Military Air Transport Service of the U. S. Air Force (MATS) were to calculate that such chartering constituted the simplest and most economical method of maintaining an extensive reserve of cargo aircraft, it would simultaneously provide a tremendous boost in both domestic cargo carrying capability and military cargo potential.

In that event the Civil Reserve Air Fleet (CRAF), which consists of 350 of the best four-engine transports of the scheduled airlines could be used almost exclusively in wartime for troop transport. For this task they are already ideally equipped and need little additional modification. Thus they would be almost immediately available for military use, whereas considerable time would be required to convert the same ships to all-cargo work. (Even then, they would be inefficient as cargo carriers.) Aside from the CRAF, the remainder of the scheduled air fleet could concentrate on domestic business and emergency transport in the event of hostilities.

U. S. Air Force Photo

Artist's concept of the Douglas C–132, Air Force transport capable of carrying 50 tons of cargo 3,500 nautical miles at cruising speeds in excess of 400 knots.



INTERNATIONAL ASPECTS OF AIRLINE FLYING

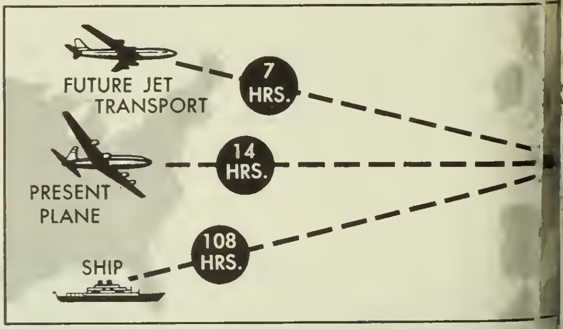
Having obtained a basic understanding of the development and expansion of scheduled airline flying in the United States, let us turn to the world scene for a broader conception of the development of civil aviation in the peacetime life of all nations and survey some of the more important factors affecting its future growth. This added perspective should enable us to assess more accurately the competitive position of the United States airline industry and the prospects for increasing its airlift capability. First, let us attempt to visualize how the speed of air communications has shrunk the world in recent decades.

In 1944 J. Parker van Zandt, a noted economic geographer, wrote, "The world is now actually smaller, measured in travel time, than were the 13 original states that united to inaugurate George Washington as President." [15]

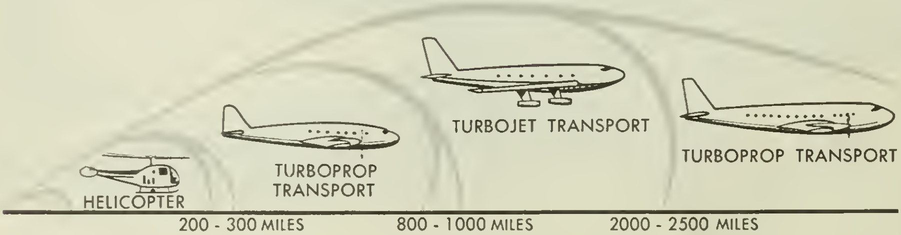
Since 1944 aeronautical engineers have increased both the speed and carrying capacity of aircraft. Whereas the average civil transport aircraft of 1946 carried but 17 passengers at 155 mph, its successor in 1956 flew 28 passengers at 200 mph. As noted previously, first-class airliners even of the conventional type exceeded these performance figures considerably. In 1952 the British airlines placed the Comet I in service and thereby became the first to use jet aircraft in commercial operations. The United States airlines initiated jet commercial service in the late 1950's with the Boeing 707 and the Douglas DC-8. Many of the 3,500 cities now served by air transport all over the world will benefit from the increased speed and carrying capacity of the jets. Transatlantic jet flights between New York and London take about 7 hours compared with the 12 to 14 hours required for conventional air travel. Throughout the world the newer types of propulsion are being adapted to the varying needs of different airline services.

U. S. Air Force Photo

De Havilland Comet III successor of the Comet I which was placed in service by BOAC in 1952.



Shrinking the Atlantic.



Coming types of transport aircraft—the European view.

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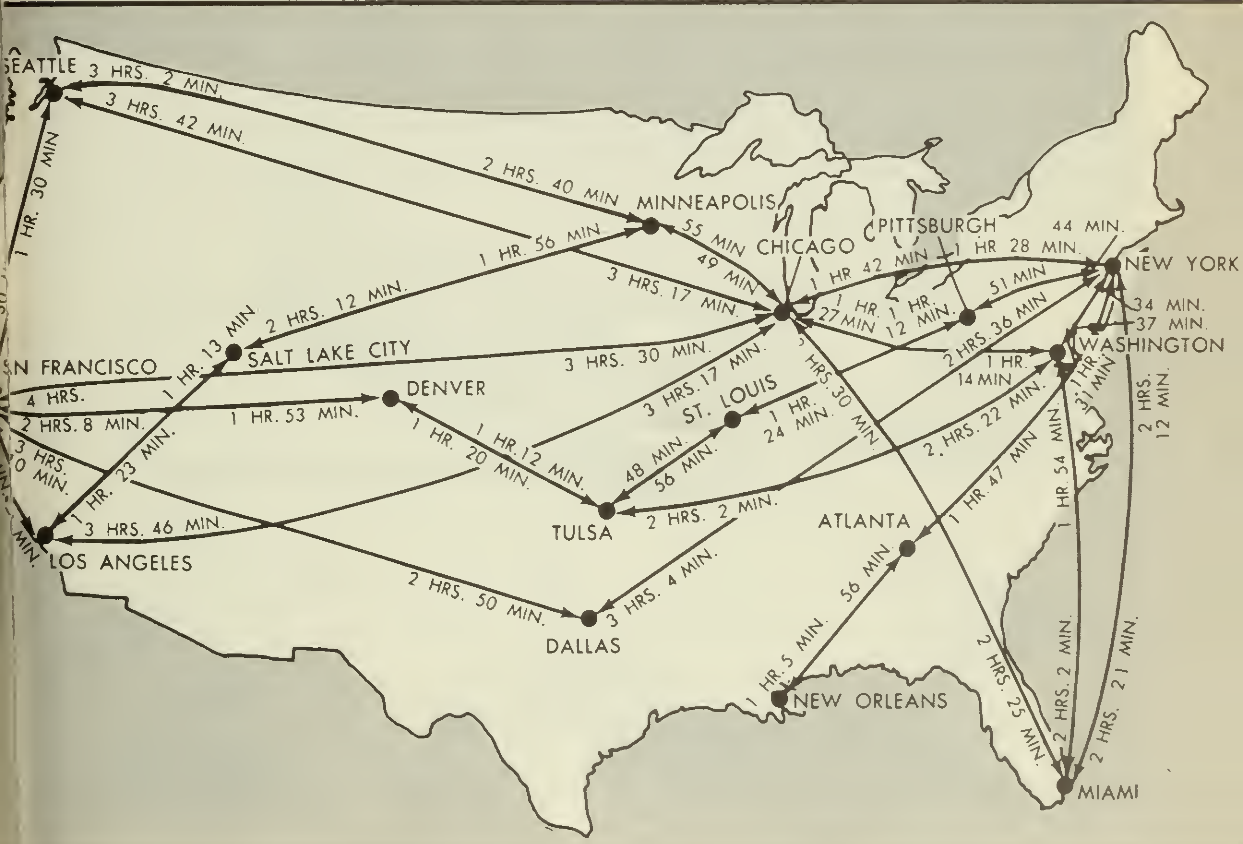
[15] J. Parker van Zandt, *Geography of World Air Transport* (Washington, D. C., 1944).

Thus through the development of air transport, i. e., air power in essence, not only can any spot on the earth's surface be reached with scant regard for terrain and weather obstacles, but it can be reached in a phenomenally short time by modern aircraft—civil or military. And today even time is losing its significance in space relationships, at least in a military sense, with the feverish development of missiles and satellites.

These advances in man's conquest of space are revolutionary even within the field of air transportation itself. As recently as 1929 the standard flight between New York and Los Angeles required 48 hours and 10 stops. It consisted of flying during the day and traveling by passenger train at night. By 1940 the same trip had been cut to 14 hours with only 3 stops. In 1953 the trip became nonstop and took a little over 7 hours. The advent of commercial jetliners in the United States was expected to reduce this figure to about 4 or 5 hours.

To obtain some conception of worldwide accomplishments in the field of airline transportation, note the graph which shows millions of miles flown by aircraft during selected years between 1929, when civil air transportation first assumed substantial proportions, and the year 1956. The figures exclude the U. S. S. R. for the entire period, Germany from 1941, Japan from 1945, and China from 1949.



Map shows possible flight times for the De Havilland Comet IVa over certain selected routes in the United States. In 1956, Capital Airlines bought 14 of these jet airliners for use in their operations. Redrawn, with permission, from American Aviation, November 19, 1956.

Worldwide increases in scheduled air transport are shown below. Tremendous advances were made by the Soviet Union, the United Kingdom, Australia, New Zealand, Canada, Brazil, Mexico, and the Netherlands. Other countries also registered important gains—notably France, India, Colombia, and the Union of South Africa. However, the preponderant share of this mileage was flown by the scheduled airlines of the United States—nearly half of the world's total in 1929 and over half since 1949.

Expansion in the Mid-Fifties: Passenger Traffic

Since World War II the world's scheduled airline flying has continued to expand at a remarkably fast annual rate. The latest

figures show no indication of a drop in this rate of growth. In 1956 the number of passengers carried was 15 percent greater than it was in 1955, and nearly 4.5 times the number carried in 1946.

Some 3 million revenue passengers were carried by the scheduled airlines in 1938, 9 million in 1945, and 78 million in 1956. The transport of 78 million people an average distance of 575 miles would represent, in equivalent terms, the "airlifting of the entire population of Ceylon to Sydney, Australia, or of carrying every man, woman, and child in Belgium, France, and Switzerland from Geneva to Lisbon, Portugal." [16] Of the 78 million passengers carried in 1956, over half were flown by United States airlines.

Revenue Passenger Mileage

Revenue passenger mileage, which provides a reliable criterion by which to measure changes in passenger traffic, also shows that the United States accounts for 60 percent or more of the passenger mileage of the world's scheduled airlines. The United Kingdom, Australia, France, Brazil, Canada, the Netherlands, and Mexico generally follow in the order named. However, their combined passenger mileage represents about one-fourth of the world's total.

The growth trend in passenger mileage is virtually worldwide. It appears that many countries have had as high a rate of increase as the United States or even higher. Between 1939 and 1952, passenger mileage in the United States and Switzerland increased about 20-fold; in the United Kingdom almost 22-fold; in Canada more than 36-fold; in Brazil more than 40-fold.[17]

According to the president of the Council of the ICAO, it is anticipated that on the basis of accumulated experience the airlines of the world will transport 100 million passengers a year for the first time in 1958. ICAO statisticians expect that by the end of 1966 the number of passenger miles flown will be between 3 and 4 times as great as in 1956, and 15 times larger than in 1946.

Cargo Ton-Mileage

The airlines of the United States, including both domestic and international carriers, in 1955 flew one-third the total scheduled cargo ton-mileage of the world (319 out of 910 million cargo ton-miles).

World Airlines and Aircraft

These tremendous quantities of cargo and large numbers of passengers are airlifted annually by a relatively small number of scheduled airlines using surprisingly small amounts of operating equipment compared with other means of transportation. There were only 220 scheduled airlines operating throughout the world in 1951—apart from the 2 in the U. S. S. R. Of the 220, more than half were in the Western Hemisphere. Over 3,800 aircraft were operated by scheduled airlines in 1951—approximately double the number used in 1938.[18] By the end of 1954 the scheduled airlines of 65 countries (exclusive of USSR and Communist China) had 4,453 planes in use, according to ICAO. About one-third of these aircraft were located in North America, while the next largest number was in Europe.

On domestic and international routes the airlines of the United States had 1,121 aircraft in scheduled service in 1951 and 1,359 in 1955. Of the latter number, 147 were in service on solely international routes. The U. S. S. R. had 850 transport-type aircraft reportedly engaged in scheduled operations in 1948.[19] ICAO figures for 1954 on other countries are as follows: United Kingdom, 540; Brazil, 287; Canada, 212; France, 210; Australia, 165; Mexico, 116. Performance data and varying degree of reliance on air transport are of course other relevant factors entering into any comparative assessment of civil air transportation.

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[16] ICAO News Release, 28 Dec. 1956, *Air Traffic Reaches Record Peak in 1956,* p. 1.

[17] W. S. and E. S. Woytinsky, *World Commerce and Governments* (New York, 1955), p. 536.

[18] *Ibid.,* p. 518.

[19] In the U. S. S. R. civil aviation is under the direction of *Aeroflot,* which controls about 80 percent of the civil air traffic. *Glavmorput,* a special organization for exploration in the Arctic areas, operates in the northern regions of the Soviet Union. Ninety-six percent of all scheduled traffic is domestic. *Aeroflot,* the government-controlled air fleet, operates on domestic routes and provides international services to satellite countries; it also connects the U. S. S. R. with Iran, Afghanistan, Mongolia, and China. Woytinsky, *op. cit.*

International Air Transportation: General Route Patterns

Now let us consider some of the underlying geographic, economic, and political factors which tend to mould the pattern of international air transport routes and will exercise considerable influence over future growth of traffic and routes. In considering these factors, first examine the general pattern of world air routes.

The volume and directional flow of air transportation generally correspond with the pattern of surface transportation which is heaviest in number of lines and volume in and between the heavily populated and commercially advanced world economic centers. Air routes, however, are usually shorter than surface routes. Airplanes travelling between two traffic centers can travel in a much more direct line than is possible for either land or sea carriers whose passage is constricted by terrain obstacles and water gateways, respectively.

The greatest volume of air traffic is generally in the most economically productive and commercially advanced regions of the world, notably the United States, Western Europe, the U. S. S. R., and Eastern Asia. In the United States the industrial and commercial regions of the northeast have developed the heaviest amount of air traffic. Specifically, New York, Newark, and Chicago alone account for about one-fifth of all air passengers. In Europe the principal traffic arteries of British European Airways are between London, on the one hand, and Paris, Brussels, Düsseldorf, Amsterdam, Nice, and Rome, on the other. Air France has a heavy volume on the Paris–London run. Scandinavian Airlines profits from a well dispersed but substantial flow of traffic throughout the heavily populated and industrial areas of Europe.

The location of the most traveled air routes of the future will continue to be governed largely by the interplay of geography, economics, and politics. The airplane's disregard of the usual geographic barriers has led many people to believe that the main commercial airways are determined solely by great circle courses between given points. We have already noted some of the specific economic factors which offset the advantages of flying true compass courses between any two points.

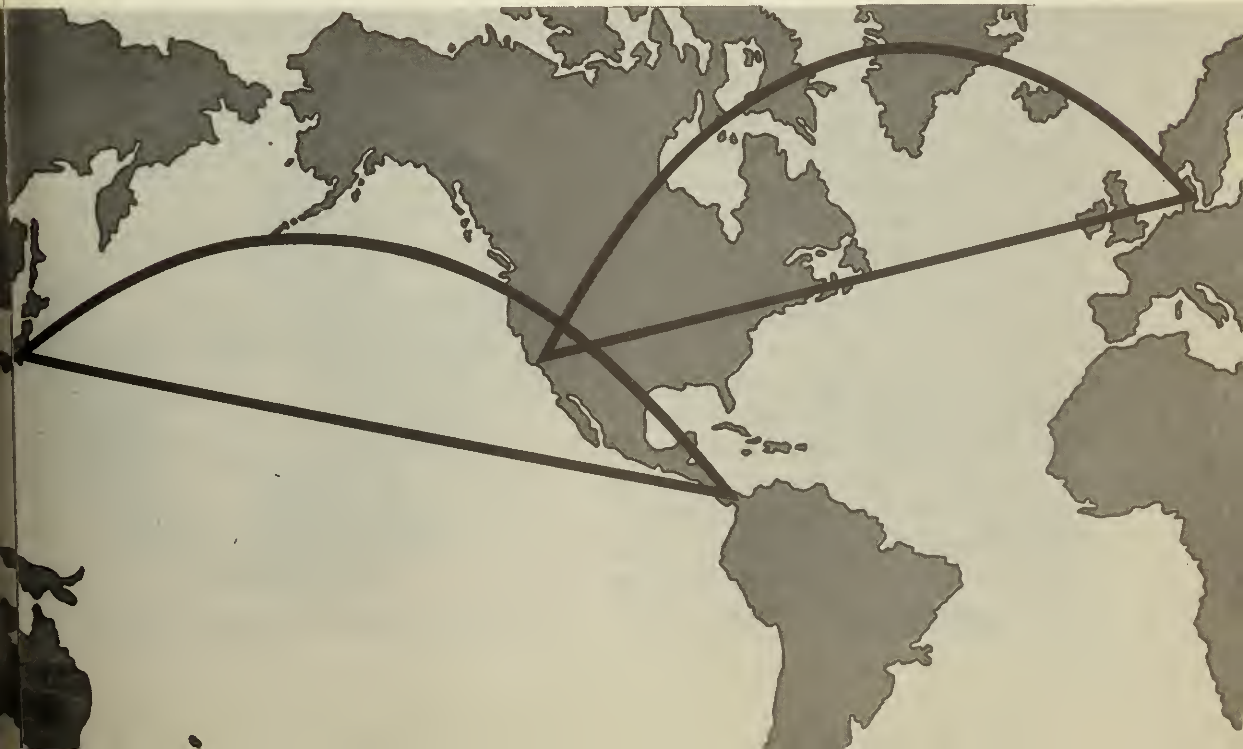
The transocean airway between San Francisco and Manila via Hawaii, for example, is 8,000 statute miles long. The great circle distance is only 6,965 miles. But to fly the great circle course would involve

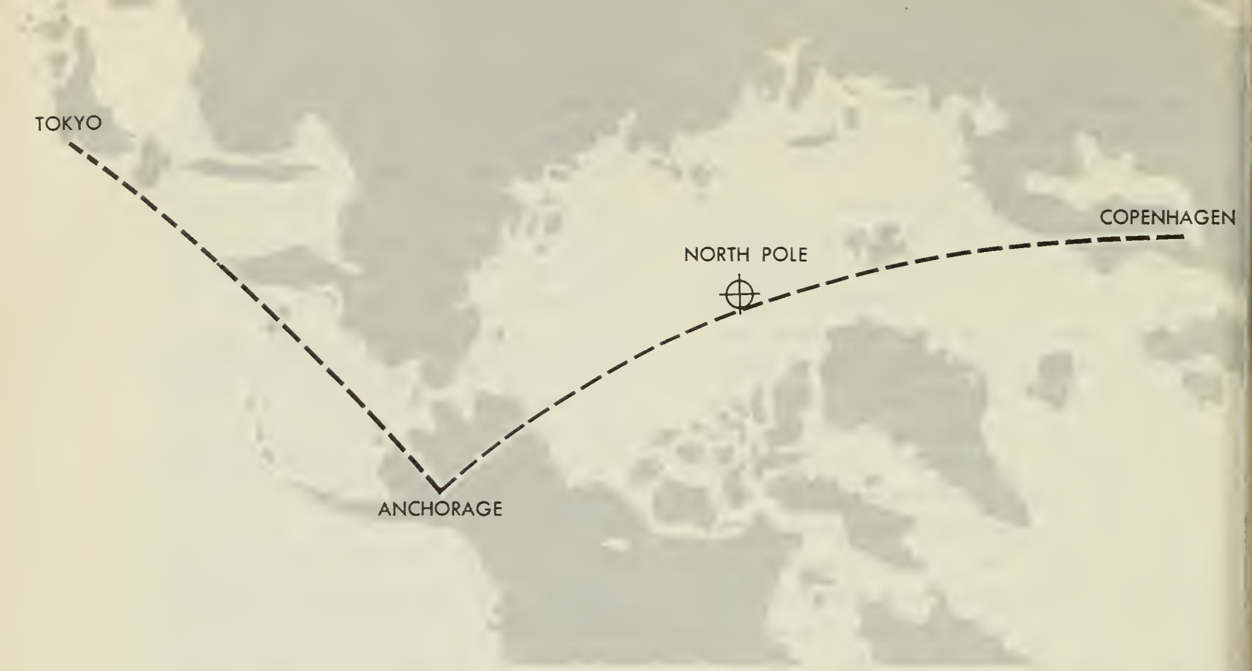
a nonstop flight over open water for almost the entire distance, passing 1,650 miles north of Honolulu and some 700 miles south of the Aleutian Islands. Such nonstop flights are obviously impractical on a commercial basis. On the other hand, aircraft traveling from New York to Europe via the northern route follow great circle courses, even though this takes them over Newfoundland which is about 1,000 miles north of New York. There are no generally worthwhile traffic points en route to divert airliners, and the great circle course over Newfoundland is much shorter than any other route to northwestern Europe.

Transpolar commercial air routes would be unprofitable unless they connected commercially prosperous areas capable of producing *bona fide* revenue traffic. The advent of larger and more efficient aircraft in the postwar era, together with intensive wartime and postwar installation of weather and navigational aids in the North American Arctic, has made it feasible for airlines such as Scandinavian Airlines System (SAS) to pioneer commercial air routes across the Arctic. In February 1957 SAS opened up its second Arctic trade route, connecting rich, densely populated northwestern Europe with Japan, the industrial and commercial leader of East Asia. A few years earlier SAS began commercial airline service across the Arctic by establishing a route from northwestern Europe to the wealthy and populous American West Coast.

However, strategic and political considerations account for sometimes radical departures from commercially feasible routes. Good illustrations are air routes linking widely separated settlements, camps, and cities in the Arctic regions, and the subsidized development of some European and

On the Mercator projection below, the shortest distance between Japan and the Panama Canal is the great circle (curved line) course between the two points. When SAS flies its regular flights between Los Angeles and Copenhagen, it flies the great circle course shown on the map rather than the longer straight line course. Redrawn, with permission, from Skylights, May 1956.





Map shows the 6,957 nautical mile Copenhagen-Tokyo route over the North Pole. SAS DC–7C flight requires 30 hours, one stop.

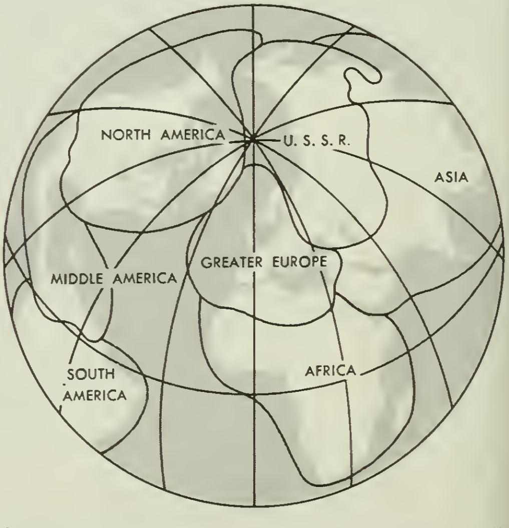
American routes. Air transport is often invaluable too in areas like the interior of South America where other means of transportation are often lacking or extremely difficult to develop economically.

World Production Centers: Locational Advantage of European Airlines

An examination of the globe will show that, except for portions of the South American area, the southern tip of India, and Oceania, all the other land areas lie in one-half of the world. This half of the globe has been termed the "principal hemisphere" by J. Parker van Zandt.

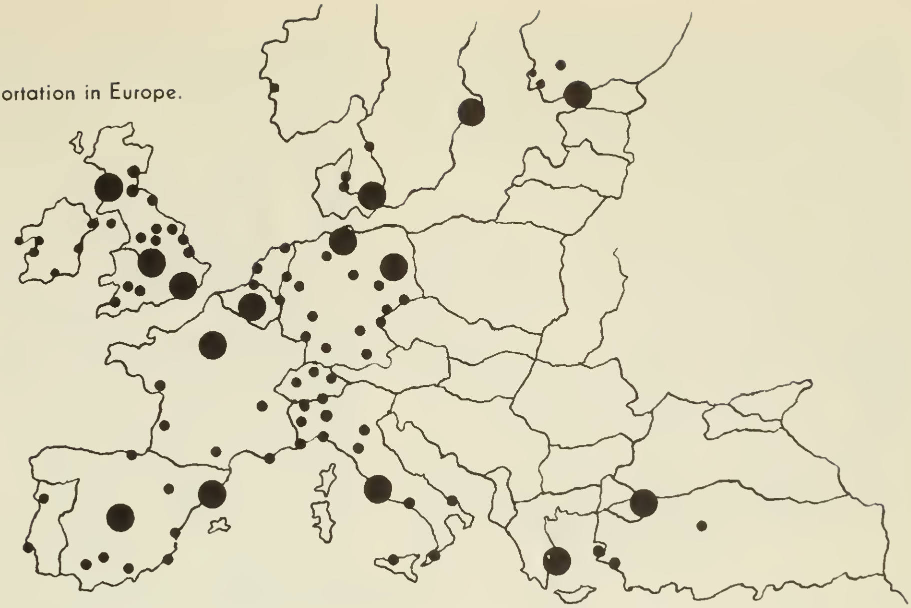
Within this hemisphere is almost nine-tenths of all the icefree land area of the world. This is the half-sphere in which the major portions of the world's natural resources, technical skill, and financial strength are found. About 95 percent of the world's population and industry is concentrated here. The center or hub of this economic world is near Nantes, France. For this reason, Europe, and France in particular, has a distinct advantage in an age when commercial travel tends to follow great circle courses when they are economically feasible.

Within the "principal hemisphere" four regions are dominant in wealth and activity. They are Greater Europe, North America, the U. S. S. R., and Asia. Over nine-tenths of the world's income is earned in these regions. Ninety-two percent of all cities of 100,000 or more are located there. Ninety-five percent of all manufactured goods are produced there.



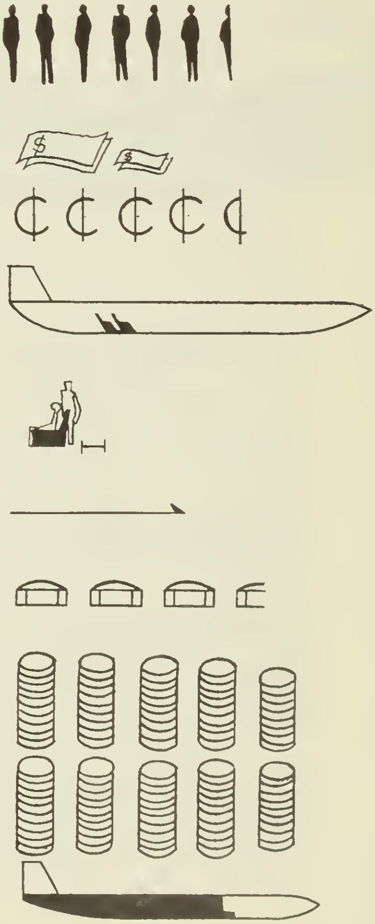
Seven major regions of the "Principal Hemisphere."

Air transportation in Europe.



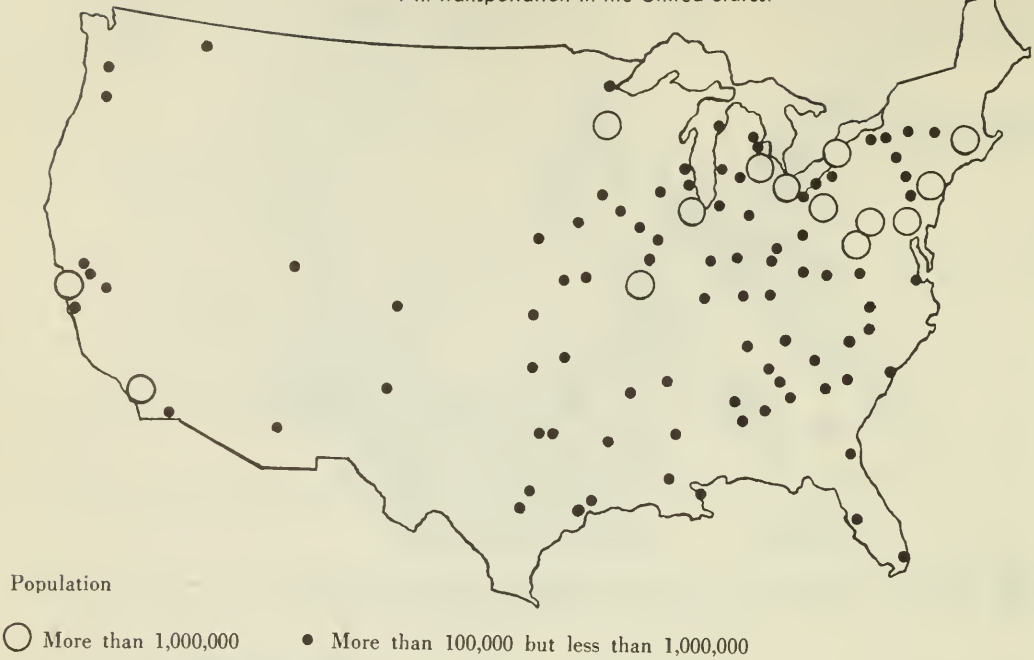
Population

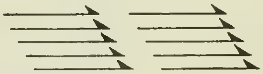
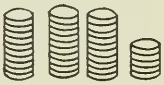
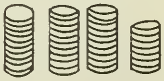
● More than 1,000,000 ● More than 100,000 but less than 1,000,000



Population (1954) (each symbol = 50,000,000 people)	:	313 million
Average income per head (1954) (each symbol = US$ 50)	:	550 US $
Average passenger fare (1953) (each symbol = US¢ 1)	:	4.5 US ¢
Passenger-km performed within the region (1954) (each symbol = 2,000,000,000 passenger-km)	:	1900 million
Passenger-km per capita (1954)	:	6 km
Average service frequency (1954) (each symbol = 1 frequency per day)	:	1
Number of airlines (1954) (each symbol = 5 airlines)	:	18
Total operating expenses per t-km performed (1953) (each symbol = US¢ 1)	:	48 US ¢
Total operating revenues per t-km performed (1953) (each symbol = US¢ 1)	:	49 US ¢
Load factor (1953)	:	63%

Air transportation in the United States.



Population (1954) (each symbol = 50,000,000 people)	:	162 million	
Average income per head (1954) (each symbol = US$ 50)	:	1850 US $	
Average passenger fare (1953) (each symbol = US¢ 1)	:	3.4 US ¢	
Passenger-km performed within the region (1954) (each symbol = 2,000,000,000 passenger-km)	:	27000 million	
Passenger-km per capita (1954)	:	167 km	
Average service frequency (1954) (each symbol = 1 frequency per day)	:	10	
Number of airlines (1954) (each symbol = 5 airlines)	:	25	
Total operating expenses per t-km performed (1953) (each symbol = US¢ 1)	:	34 US ¢	
Total operating revenues per t-km performed (1953) (each symbol = US¢ 1)	:	37 US ¢	
Load factor (1953)	:	56%	

The location of these four dominant egions and the extent of their commercial activity now determine and, for the fore-eeable future, will continue to determine he over-all pattern of world trade routes. Between and over North America and Eurasia, which includes the other three areas, the airways carry heavy traffic.

Located at the periphery rather than at he center of the world's principal hemsphere, North America is at a certain disadvantage. Obviously American airlines have to haul commercial passengers and goods longer distances to and from the other hree major areas than do their competitors. For the time being, however, these disadvantages of global location are largely offset by the lead the United States has achieved n commercial aviation. Increased efficiency in airplane operation and continued echnical advancement have not only lessened but have essentially overcome this handicap of geography.

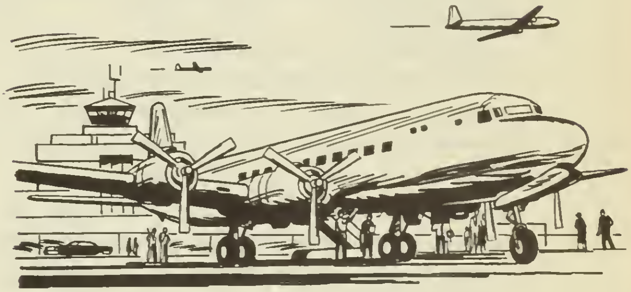
The main economic compensation to the borderland position of the United States is ts great wealth. It produces such a large hare of the world's commerce that air routes o and from North America cannot but be heavily traveled.

Advantages of the United States Air Position

At the same time the relatively peripheral ocation of the United States in the economic world is offset by incomparable advantages in political freedom of movement in all directions.

With the Atlantic on the east, the Pacific on the west, and the Caribbean and the Gulf of Mexico on the south, we have virtually complete freedom to fly over the high seas toward every continent. In addition, the United States has the peculiar good fortune as a nation state to have friendly neighbors on each great land boundary.

Nevertheless, the factors of distance from Old World centers and limited aircraft range have generally made it necessary for U. S. airliners en route to Europe, Africa, and Asia to refuel at intermediate bases under the control of friendly foreign powers. As a rule, very little compensatory traffic can be picked up at these intervening points. To the extent that such stops at the gateways of the Old World can be safely eliminated through technological improvement of aircraft, America's already strong air power position will be improved. In addition to the absolute gain in range, our ability to fly commercially into Europe or Africa will be easier to maintain if American air services command a choice of gateways and landing areas.



AIRLINE FLYING: SUMMARY AND CONCLUSIONS

In our study of scheduled air transportation, we have repeatedly seen that the major elements of air power are mutually interdependent. Civil aviation depends on the aeronautical industry to furnish the planes for its transport fleet. The economic viability of the air transportation industry is a function in part of aeronautical technology and manufacture. The development of the Boeing 247 and the DC–3 greatly improved the efficiency of early air transportation. With the development of an air vehicle capable of sustaining itself economically, it became possible for the airlines to expand. Today, similarly, the advent of jet airliners capitalizing on the efficiency of turbo-prop and turbo-jet engines promises to revolutionize commercial air transportation, not only in speed, but also in economy of operation and in comfort of travel. Largely because of these factors and the spur of competition, orders for new airliners amounting to billions of dollars have been placed by the airlines. This in turn is stimulating the technological art and the aircraft manufacturing industry.

Conversely, the financial crisis of the airlines in 1947 adversely affected the aircraft industry. Cancellation of airline orders for new equipment stifled development of further designs and caused the cutback of production, which had already been severely curtailed by the virtual collapse of military procurement.

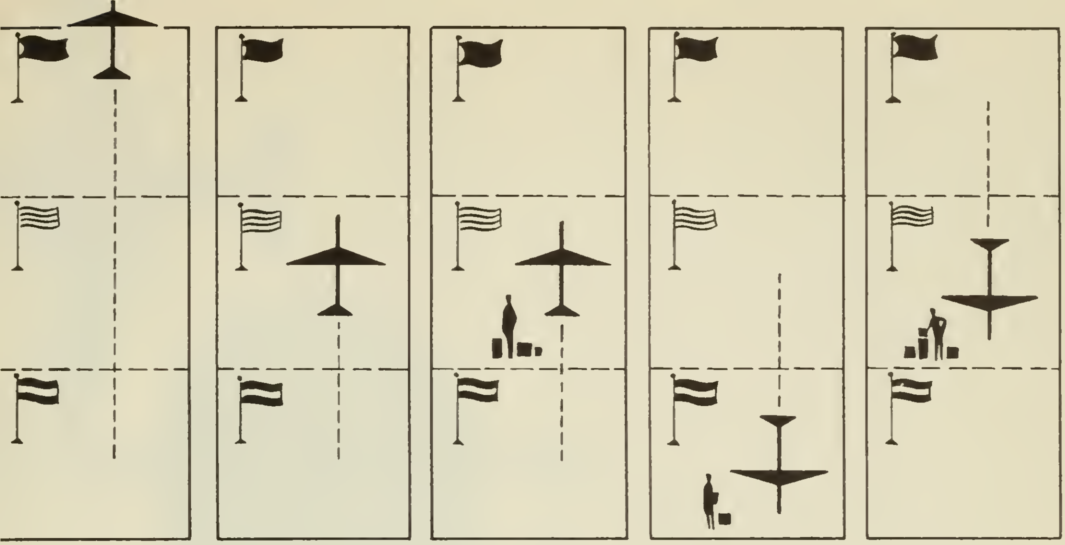
Resolution of the consequent crisis in which American aviation found itself demonstrated vividly the interdependence of various elements of air power: civil and military aviation, the aircraft industry, aeronautical facilities (the airways and aids to navigation), technological research, and governmental policy. Without a favorable governmental policy, it would have been impossible for the two major civilian components of air power to sustain themselves economically after undergoing the economic shocks of the early postwar years. Governmental policy could not, except at the cost of imperiling the national security, permit the dissolution and collapse of these twin pillars of military air power.

Development of an integrated national aviation policy soon clarified the true relationship among these elements and definitely established air power as the basis for American security. Recognition of air power as the mainstay of defense in turn involved the support and rejuvenation of both the airlines and the aircraft industry. The later expansion of the airlines of course contributed in turn to the development of technology and to the economic stability of the aircraft industry, although the main stimulus of the latter was military orders.

The policy of support for the airlines necessarily involved the improvement and expansion of another element of air power, that of aeronautical facilities. The buildup of airways and intensification of technological research on traffic control and navigational devices offered the best means of promoting the health of the airlines and increasing regularity and safety of service. This again illustrated the importance of technology and in turn the level of education and skill of the American people as sustainers of the primary elements of air power.

The subsequent recovery and expansion of the airlines permitted the larger lines to become strong enough to stand on their own feet economically. Attainment of self-sufficiency by the trunk lines, which constitute 75 percent of the airline industry, demonstrated the economic maturity of the industry. Thus the policy of governmental subsidization was vindicated on economic as well as political grounds.

The recognition of the interrelationship between the airlines and national defense in 1947 did not signify the adoption of a new policy. Rather it was an elucidation and expansion of a generally consistent governmental policy which had nurtured the development of civil airlines since 1918. The break in governmental policy in 1934 proved to be only temporary. Even the 1934 policy, which sought to put the airlines on a purely economic footing, was beneficial to national defense in the long run because it forced a healthy readjustment within the industry. The renewed vigor of the airline managers was responsible for much of the later success of the airlines in selling air travel to Americans. In the Civil Aeronautics Act of 1938, Congress reaffirmed its support of air transportation as an instrument of national policy. In passing this act, Congress no doubt was influenced by the role which air power was assuming in German and Russian rearmament and in military operations in Spain.



Freedom to fly across territory of any contracting state without landing

Freedom to land for refueling and repair

Freedom to discharge passengers, mail and cargo in any contracting state

Freedom to take on passengers, mail and cargo destined for the country whose flag the aircraft flies

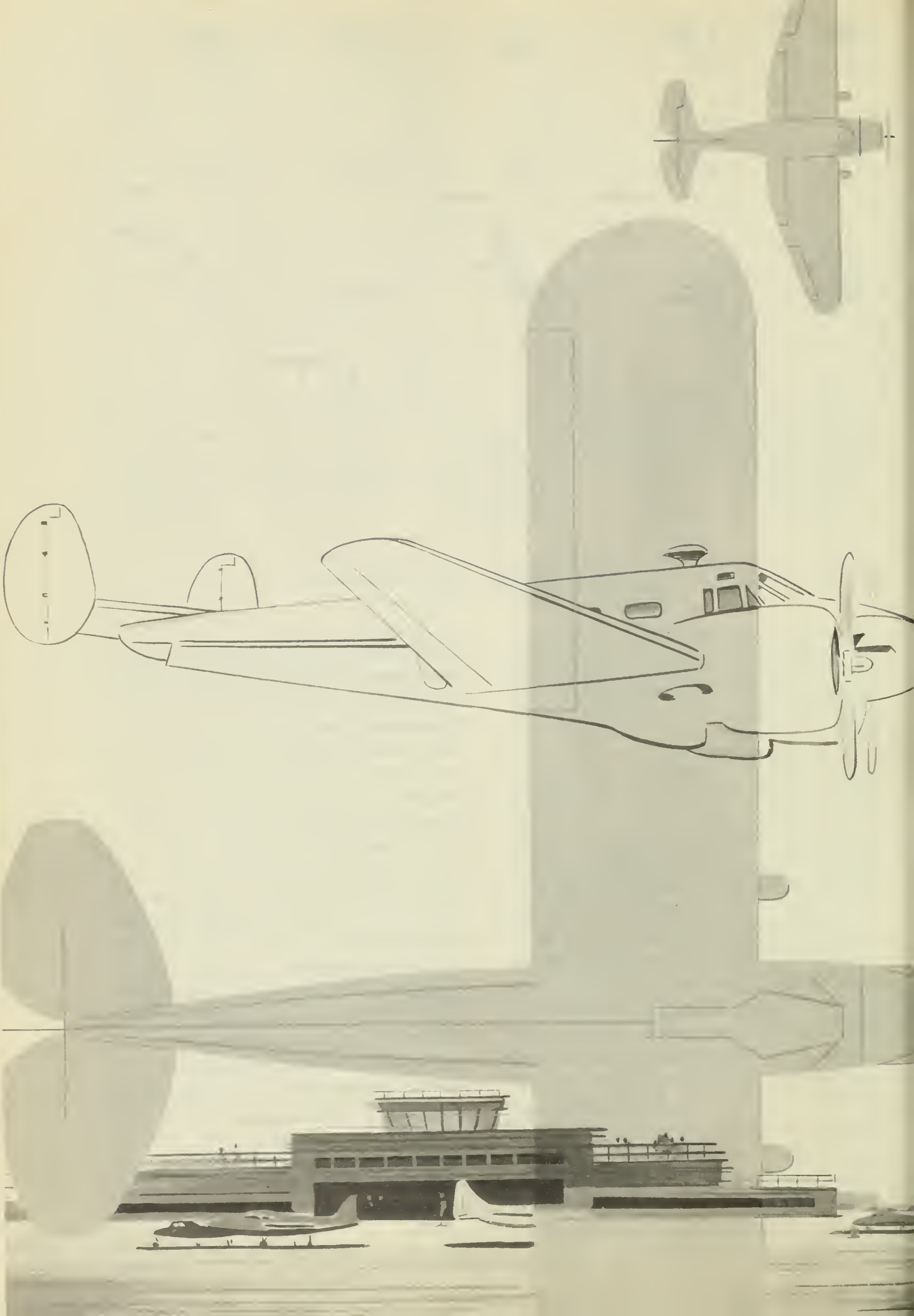
Freedom to carry passengers, mail, and cargo to and from the territory of any contracting state

Five freedoms of the air embodied in international agreements on aviation.

The wisdom of the Government's policy was demonstrated in World War II when the airlines again proved the intimacy of the connection between air transport and airpower.

That other governments have long recognized this interrelationship was demonstrated in Europe even before World War I by the promotion of airplane and engine development. That earthshaking conflict radically transformed Europe politically, ideologically, economically, and socially, and significantly altered world power relationships. Impelled by the raging torrents of nationalism, militarism, and imperialism which had broken through the floodgates in World War I, many governments hastened to promote the growth of national and imperial airlines, as well as merchant marines and war industries. The Paris Air Convention in 1919 specifically recognized the exclusive right of every state to control the airspace above its territory in peacetime, thus making impossible any "freedom of the air ocean" comparable to that existing on the high seas. Though later international air conferences did not materially change this principle, it became outmoded by technological conquests of space in the 1950's.

The continued existence of political barriers prevents civil air transportation from developing its true potential. Nevertheless, international air line travel has grown rapidly, especially since World War II. Notwithstanding its unprecedented destructiveness, the war proved a boon to the progress of aviation in general and to air transportation in particular. For the first time air transportation became a major component of the world's transportation industry. The effects of this experience and of the technological revolution created by the war will continue to influence civil aviation for many years. The advent of jet airlines in the United States and their operation on foreign airlines since 1952, in combination with the development of new all-cargo transports, point to the imminence of a great new era in world air transportation.



PART 1

CHAPTER 6

General Aviation

SCOPE OF GENERAL AVIATION

THERE ARE many different kinds of civil flying besides scheduled air transportation. Ranked by amount of annual flying time, they are business flying by private firms, farmers, ranchers, and professional men; pleasure flying; flight instruction; commercial agricultural flying; and miscellaneous aerial operations. Together these activities are called *general aviation.*[1] Commercial aspects of general aviation employ the airplane in a considerable variety of ways and are treated more fully than others such as pleasure flying or flight instruction which are by their nature largely self-explanatory.[2]

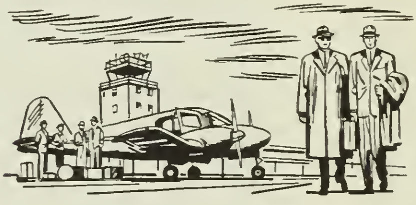
General Aviation in the United States and Abroad [2]

General aviation has grown rapidly throughout the world since the First World War. In few places, however, has its development been as spectacular as in the Western Hemisphere. In 1938 business firms, private individuals, and unscheduled carriers the world over owned about 20,000 general aviation aircraft (total registered civil aircraft, minus the number of scheduled airline planes). More than half of these planes—10,800—were based in North America. During the following decade war plagued the lands of Europe and depleted their stocks of equipment and their facilities. While that continent languished, other areas forged rapidly ahead. Measured by number of planes, general aviation more than doubled in Asia (330 to 800), jumped seven-fold in Latin America (500 to 3,500), and skyrocketed in the United States (10,000 to over 90,000). By 1954, however, this latter figure had dropped to 60,000.[3]

The middle fifties, nevertheless, saw the general aviation aircraft of the United States flying three times as many hours as all the scheduled airlines in the country (domestic, international, and territorial). These planes flew the equivalent of 45,000 trips around the world. As might be expected, such privately owned and corporation aircraft greatly outnumbered scheduled airline planes—44 to 1 (60,000 against 1,400).

National Significance

Both light and heavy planes in the general aviation industry play an important part in the daily operation of the nation's business and agriculture. Moreover, in time of crisis, they can furnish indispensable aid. The multi-engined fleet of over 2,000 planes—larger than the entire airline armada—represents a significant large-scale transport potential. For their part, many of the lighter, easy-to-land planes now scattered throughout the country might in a national emergency "become the chief link between life and death, bringing the supplies and providing the communications necessary to re-establish devastated areas." [4] This potential will become evident in the treatment of the effect of general aviation aircraft upon the functioning of the American economy.



BUSINESS FLYING [5]

Business flying is all flying done by corporations, companies, or individuals in their own aircraft in pursuance of their enterprises or professions. Some firms fly executives and technicians from one plant to another, while others ship merchandise and critical repair parts from point to point. Salesmen, farmers, ranchers, doctors, lawyers, engineers, and many others find the airplane vital to their personal business operations. In addition, the trend toward decentralization in defense industry has accelerated the

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[1] Other designations for these activities are *general utility aviation, fixed base flying, miscellaneous commercial operations,* and *local air services.*

[2] Based on W. S. and E. S. Woytinsky, *World Commerce and Governments* (New York, 1955).

[3] This reduction was apparently caused by the withdrawal of some war surplus planes and the initiation of a new CAA system of determining numbers and categories of general aviation aircraft in the U. S.

[4] *Aviation Facts and Figures,* 1956.

[5] Most of the material in this section is based upon the CAA "Survey of Aircraft Use," published under the title, *The Airplane at Work for Business and Industry* (*AWBI*), (Washington, 1955). No similar surveys were made in 1956 or 1957. Estimates are based on 1955 findings unless otherwise specified.

[6] *Aviation Facts and Figures,* 1956.

HOURS FLOWN IN GENERAL AVIATION BY TYPES—1931–55

[Thousands of hours]

Year	Total hours	Business [1]		Commercial [2]		Instructional		Pleasure		Other [3]	
		Hours	Percent	Hours	Percent	Hours	Percent	Hours	Percent	Hours	Percent
931	1, 083	152	14	281	26	307	28	343	32	.....	......
932	877	130	15	215	25	223	25	309	35	.....	......
933	795	129	16	200	25	198	25	268	34	.....	......
934	846	121	14	207	24	217	26	301	36	.....	......
935	954	132	14	229	24	292	31	301	31	.....	......
936	1, 059	122	12	245	23	380	36	312	29	.....	......
937	1, 173	156	13	227	19	432	37	358	31	.....	......
938	1, 478	188	13	254	17	577	39	459	31	.....	......
939	1, 922	246	13	332	17	755	39	589	31	.....	......
940	3, 200	314	10	387	12	1, 529	48	970	30	.....	......
941	4, 460	250	6	511	11	2, 816	63	883	20	.....	......
942	3, 786	270	7	473	12	2, 680	71	363	10	.....	......
946	9, 788	1, 068	11	943	10	5, 996	61	1, 686	17	95	1
947	16, 334	1, 966	12	1, 279	8	10, 353	63	2, 616	16	120	1
948	15, 130	2, 576	17	1, 066	7	8, 701	58	2, 606	17	181	1
949	11, 031	2, 615	24	1, 449	13	4, 187	38	2, 732	25	48	(4)
950 [5]	9, 650	2, 750	28	1, 500	16	3, 000	31	2, 300	24	100	1
951	8, 451	2, 950	35	1, 584	19	1, 902	23	1, 880	22	135	1
952	8, 186	3, 124	38	1, 727	21	1, 503	18	1, 629	20	203	3
953	8, 527	3, 626	42	[6] 1, 649	19	[7] 1, 248	15	1, 846	22	158	2
954	8, 963	3, 875	43	1, 829	20	1, 292	15	1, 920	22	47	(4)
955 [8]	9, 500	4, 300	45	1, 950	21	1, 275	13	1, 975	21	.....	......

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[1] Includes flying for corporate or executive pur-oses as well as flying by individuals, including armers and ranchers, on personal business.

[2] Includes contract, charter, industrial and com-nercial agricultural flying.

[3] Testing, experimental, ferrying, Civil Air Patrol, tc.

[4] Less than ½ of 1 percent.

[5] Data statistically computed from trend since no ormal survey was conducted for this year.

[6] Military contract flying has been excluded.

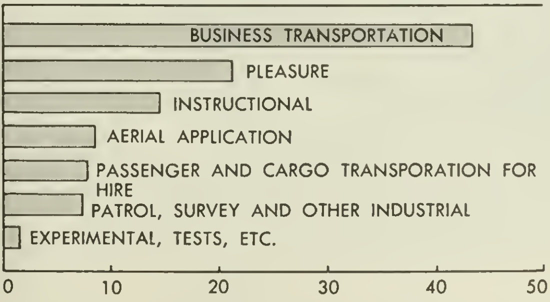
[7] Excludes military flight instruction by civil contractors.

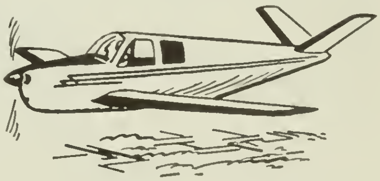
[8] Preliminary.

NOTE.—This table excludes all aircraft operated by the scheduled airlines and by CAA. Data for war years are not available.

Source: 1931–42 CAA Non-scheduled Flying Reports. 1946–55 CAA Annual Survey of Aircraft Use.

PERCENT OF HOURS FLOWN BY ALL AIRCRAFT BY TYPE OF FLYING 1954





demand for executive transports as a faster means of travel. "Today's businessman cannot spend three or four days traveling to do one or two days of productive work. Through the use of executive aircraft, he can double and often quadruple his productivity." [6]

Business flying is growing more rapidly than any other segment of general aviation in the United States. It has expanded fourfold since the Second World War. By the mid-fifties people making business flights logged about four million flying hours—more than the total of all the United States scheduled airlines put together. In 1957 business pilots were flying almost as many hours as all other general aviation pilots.[7] And by 1970 business flying time should double to a new peak of 10 million hours, according to CAA statisticians.

Apart from the tremendous general inherent advantages of the airplane for business travel, the explanation for the sharp upward trend in business transportation lies in the achievements of the aircraft industry. Manufacturers have been able to market, at a reasonable cost, designs that "will do the job" safely and economically.[8] Technological efficiency has made the airplane an economical tool for American businessmen.

The term, "business aircraft," spans a wide range of designs. Virtually every plane from the four-engined turboprop Vickers Viscount on down is being used for business transportation. And firms such as Continental Can Company have ordered several jet Fairchild M–185F executive transports with deliveries scheduled to begin in 1960.

In all probability, new aircraft like the Viscount and M–185F will not affect the

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[6] *Aviation Facts and Figures*, 1956.

[7] E. J. Bulban, "Business Flying Shows Sharp Upswing," *Aviation Week*, Vol 66 (25 Feb 1957), p. 276.

[8] R. B. Prewitt, "The Future of Business Flying," *Aviation Age*, Vol 25 (June 1956), Section I, page 10.

business flying picture greatly for some time to come. It seems likely that for the sake of holding down critical production costs old standbys will be improved rather than replaced. Seemingly new business aircraft types will probably be refinements of proved military designs.

Fundamental issues of design aside, there has been and is a trend toward larger planes. This shift is reflected in the changing composition of the aircraft industry's production of general aviation aircraft. The small two-place airplane was in great demand right after the Second World War, but it soon gave way to larger four- to six-place types. Coming in single- and twin-engine versions, the bigger planes made up four-fifths of all general aviation aircraft produced in 1952. Equipped with two-way radio, these larger models today enjoy practically all-weather capability and fly at higher speeds—thus greatly adding to their usefulness. Because of its more modest price, the single engined plane remains the most popular type and seems destined to continue to dominate the general aviation field for years to come.

Shown here are some modern business and executive airplanes. Many firms have two- and four-engined aircraft identical to those used by the airlines except for interiors.

Cessna 310. This twin-engine executive plane cruises at 213 MPH and has space for five passengers. ▲

Eight-place twin-engine Beechcraft Super 18 executive transport. It has a top speed of 234 MPH and a range of 1,626 miles. ▼

Courtesy of Beech Aircraft Corporation

Beechcraft Bonanza, all metal four-place monoplane with a top speed of 210 MPH and a range of 1,000 miles. ▼

Courtesy of Beech Aircraft Corporation

Because of the extent of their needs and the size and speed of the planes they use, some corporations have found it worth their while to employ regular professional pilots. In this way they get maximum benefits from aircraft ownership. Regular pilots handle approximately 3,500 executive aircraft. These men usually earn from $6,000 to $15,000 a year, salaries which are about on the airline pilot level.

Nineteen thousand general aviation aircraft are used almost all of the time in direct support of such activities as manufacturing, merchandising, banking, finance, construction, transportation, utilities, mining, and oil production. Business concerns operate more than half of these planes.[9] Private individuals own the remainder, except for a few hundred in use by governmental agencies. An additional 15,000 aircraft, owned by small companies and private individuals, are also engaged in business flying activities, but only on a limited part-time basis.

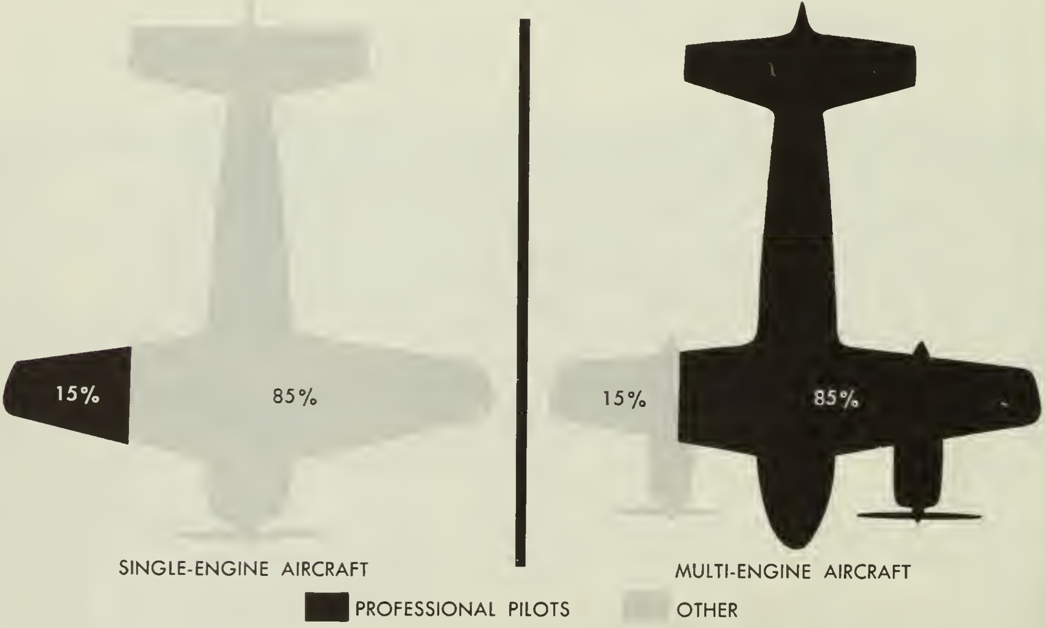
Many sections of the country are making special efforts to attract business fliers. Detroit, Cleveland, and Chicago have provided airstrips convenient to their main business districts. In the case of Chicago, special facilities to meet business aircraft needs have been developed at the $1 million Skymotive Terminal at O'Hare Field.

The growth curve in business flying is depicted graphically in the accompanying chart.

Commercial Advantages

The airplane by its tremendous speed has shrunk the distances which must be traversed by businessmen in an economy characterized by ever greater complexity and physical dsipersion. The four-fold increase in business flying in the first postwar decade is proof that industry has found in the air-

Percent of Business Aircraft Flown by Professional Pilots.
Calendar Year 1954



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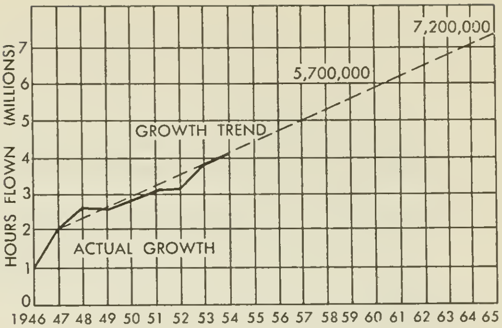
[9] Among the concerns using aircraft as business tools are Container Corp., Endicott Johnson Corp., Esso Shipping Co., Corning Glass Works, Firestone Tire and Rubber Co., General Tire & Rubber Co., General Motors Corp., Continental Oil Co., Sun Oil Co., Ohio Oil Co., Gulf Oil Co., International Business Machines, Richfield Oil Corp., Shell Oil Co., Parker Pen Co., Gerber Products Co., Mason Dixon Lines, Inc., National Cash Register Co., and Tennessee Gas Transmission Co.

lane a useful and efficient tool. The busi-
ess aircraft today gives reliable service at
easonable cost. Continual improvement
aircraft design has made this possible and
as done for business flying what the de-
elopment of advanced transport types in
ie 1930's did for the scheduled airline in-
ustry. In both cases, technological prog-
ess provided a foundation for later rapid
rowth. Performance aside, the great vir-
ie of the company-owned aircraft lies in
ie fact that it saves precious time and
ergy.



CAA forecast of business flying activity shows hours flown are expected to double by 1965, reaching 7.2 million hours.

Civil Aeronautics Administration

COMMERCIAL FLYING [10]

gricultural Flying

The airplane has been used as a tool in
griculture since 1919 when the United
tates Department of Agriculture (USDA)
erially dusted fruit trees infested with cater-
illars. From this pioneering experiment
emmed the aerial application business in
griculture. More than 200 different types
f crops are now treated from the air. *Agri-*
ultural aerial application means the use of
ie airplane as a substitute for farm imple-
ients and ground vehicles in the process of
ood and fiber production. Among the agri-
ultural activities that lend themselves to the
mployment of aircraft are spraying, dusting,
eeding, and fertilizing.

The success of the experimental aerial
usting of fruit trees led the Department of
griculture in 1922 to test the same tech-
ique on Louisiana cotton fields infested with
he boll weevil. The Army made two air-
lanes—Curtiss J–N–4D's—available to the
JSDA for these early experiments.

In 1923 the Huff-Deland Aero Corpora-
ion of Ogdensburg, New York became the first commercial company to enter the new general aviation field of aerial application. This company designed its own aircraft for crop control operations, the Huff-Deland Model H–D31, and worked under contract to the USDA.

In the late 1920's other commercial operators moved into the field, doing their work with converted commercial airplanes. Though the 1930's witnessed continued growth of this business, it was not until after World War II that aerial spraying and dusting increased rapidly. This expansion resulted from the development of agricultural chemicals better suited to aerial application, the availability of inexpensive war surplus aircraft, and the existence of a large pool of ex-military pilots. Today aerial

Spraying accounted for nearly half of all agricultural flying in 1954.

U. S. Air Force Photo

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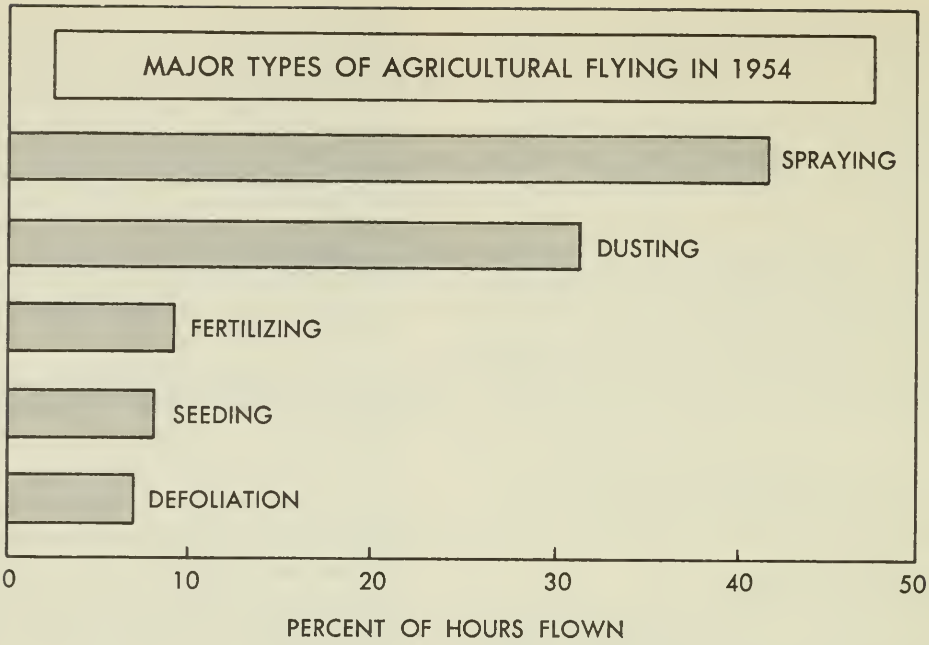
[10] The material in this section is derived pri-
iarily from the extensive Survey of general avia-
on activity conducted by the Civil Aeronautics
dministration in 1955 and published under the
itle, *The Airplane at Work for Business and*
ndustry.



Civil Aeronautics Administration, Annual Survey of Aircraft Use

dusting and spraying account for roughly three-quarters of the flying done in aerial application.

Most aerial dusting seeks to control insects and fungus diseases which attack crops. Two-thirds of all the aerial dusting done in the United States is concentrated in the South where good cotton crops depend heavily on such operations.

In recent years aerial dusting has declined in importance, while spraying has become increasingly popular. This is due to several factors. Spraying can be performed safely at higher wind velocities than are permissible for dusting; and sprays not only adhere to plants better but also require less pure chemical. In forested areas, moreover, aerial spraying is considerably more effective than either ground spraying or aerial dusting and is more economical. These characteristics of efficiency and economy were notable in "Operation Budworm," one of the greatest forest-spraying efforts on record, which took place in Canada during June 1952. In a two-week period 23 airplanes sprayed a large afflicted area and saved $100 million dollars worth of pulpwood at a cost of only $500,000.

Other Agricultural Uses of the Airplane

Aerial spreading of fertilizer is not uncommon in the South and Southwest. It is particularly useful in rice production.

Aircraft also have been found suitable for broadcast sowing of certain seeds from the air. Crops which can be profitably planted by aerial seeding include grasses, grains (especially rice), cover crops, and oil seed crops other than cotton. As in the case of fertilization, aerial seeding is predominantly used in the South and Southwest where rice is an important crop. Furthermore, the airplane has successfully undertaken tasks of reforestation and pasture reseeding. It is also employed to distribute defoliation chemicals, that is, agents which cause plants to lose their leaves and mature more rapidly. Defoliation facilitates mechanical cotton picking and makes possible a higher quality product.

The remaining activities in the field of aerial application are dependent upon the variables of weather and insect invasions, and therefore fluctuate considerably from year to year. One of the most important agricultural services rendered by the airplane alls within this general classification and ʼarrants brief description: locust baiting. 'rom time immemorial grasshoppers have ıtermittently descended in hordes upon dentary man, ruined his crops, and ıreatened or caused famine. In 1951 a lague of locusts struck Iran, and the governıent requested help from the United States. ;ight small planes specially equipped for ıe task were dispatched to Iran, together ith pilots and technicians to carry out the peration. The planes and men were transorted by large cargo aircraft, along with 3 tons of insect toxicant. Within four days ver 50,000 acres of crops were saved in 18 calities. Similar accounts of amazing cust kills have been reported in Pakistan, ndia, the United States,[11] and Canada. 'hese emergency air operations have often een the salvation of crops and grazing ınd. Timely action of this nature is of ıe greatest significance, especially in areas of subsistence farming. The speed and penetrating power of the airplane makes it an uniquely effective defensive weapon against masses of invading insects.

Other aerial application activities include the inspection of crops and fallow land, spraying operations for sanitation purposes, and the unique task of chasing birds from rice fields.

Widespread acceptance of aerial application is indicated by the fact that one out of every 12 acres under cultivation in the United States is treated from aircraft. The impact of aerial application on the consumer is also considerable. "It can safely be said that every person in the nation eats, touches, or wears something every day of the year that an agricultural airplane treated beforehand." [12]

HOURS FLOWN IN AERIAL APPLICATION ACTIVITIES, CONTINENTAL UNITED STATES, 1952–54

Activity	1952	1953	1954
praying	219, 551	262, 183	273, 439
usting	278, 970	266, 848	209, 357
ertilizing	62, 908	64, 011	62, 736
eeding	51, 414	53, 433	52, 396
efoliation	50, 714	49, 633	49, 342
hecking crops	8, 523	5, 782	8, 570
praying towns—pest control	8, 143	7, 561	5, 884
hasing birds from rice fields	8, 470	4, 819	5, 877
rasshopper baiting	3, 200	5, 266	2, 984
ntifrost agitation	13, 528	1, 540	809
hecking fallow land	1, 616	1, 159	756
gitating cherry trees	240	53	51
nocking fruit from trees	0	30	25
Total, all types	707, 277	722, 318	672, 226

Civil Aeronautics Administration, Annual Survey of Aircraft Use

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[11] In two weeks during 1952 aircraft sprayed enough poison bran on 2.7 million acres of western range land to kill 175,000 tons of grasshoppers.

[12] CAA, *AWBI*, p. 12.

AIRCRAFT USED IN AERIAL APPLICATION

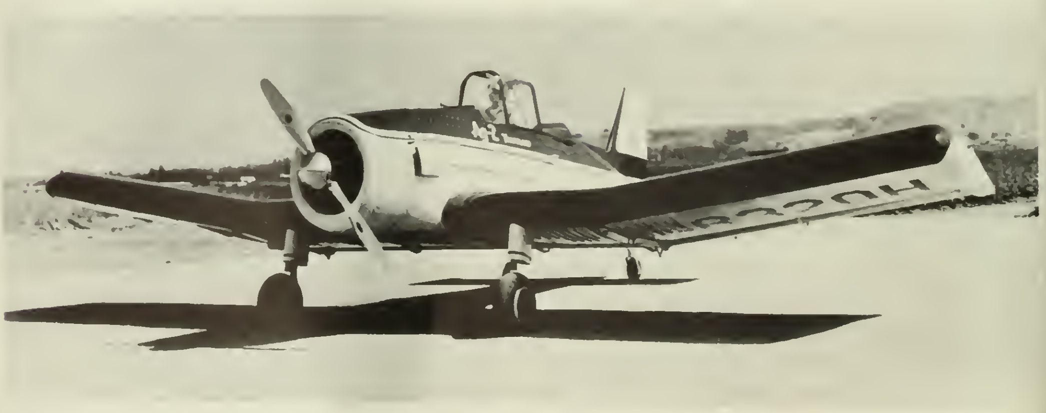
An estimated 2,600 aircraft are engaged in aerial spraying operations, and 2,300 in aerial dusting. No doubt some of these serve in a dual capacity. Light- and medium-weight planes predominate, although a small number of heavier craft and helicopters are also used. The Piper is the most common light plane, while the Stearman is the typical medium-weight type.

Although many of the aircraft still in use for aerial application operations are war surplus types, postwar light planes have begun to take over the field. The trend is toward the development of specially designed aerial application planes. Lamson Aircraft Company is building the Air Tractor, a single-engined biplane designed to carry a payload of about 2,500 pounds. Fletcher Aviation Corporation has a single-engined, low-wing, all-metal plane which has found acceptance in New Zealand and is to be marketed in this country as well. Transland Company is working on the AG–2 airplane, a low-wing, all-metal monoplane with a payload of 2,000 pounds. Other aircraft under development for agricultural use include the Call A5, Taylorcraft Topper, Cessna 323, Piper AG-3.

Though there has been progress in the design and production of agricultural aircraft, the output of properly trained agricultural pilots has lagged. In an effort to end the shortage, Texas A&M College, in cooperation with the CAA and the Texas Aerial Applicators Association, recently began to offer a six-weeks course on the fundamentals of agricultural flying for experienced pilots with commercial licenses and at least 500 hours of solo flight time.

Patrol, Survey, and Other Industrial Flying

The expanding use of aircraft in patrol and survey activities is a natural result of the fact that the airplane can do such work supremely well. The airplane's speed and freedom from surface conditions and terrain obstacles permit pilots or crews to make observations over wide areas in a minimum of time and with the expenditure of comparatively little manpower. Another unique advantage of the airplane is that it also affords the aerial observer (or camera) a more complete view of the situation on the ground and makes possible a more accurate assessment of space relationships than would otherwise be possible. The variety of uses to which general aviation aircraft have been put in patrol and survey work is surprising.

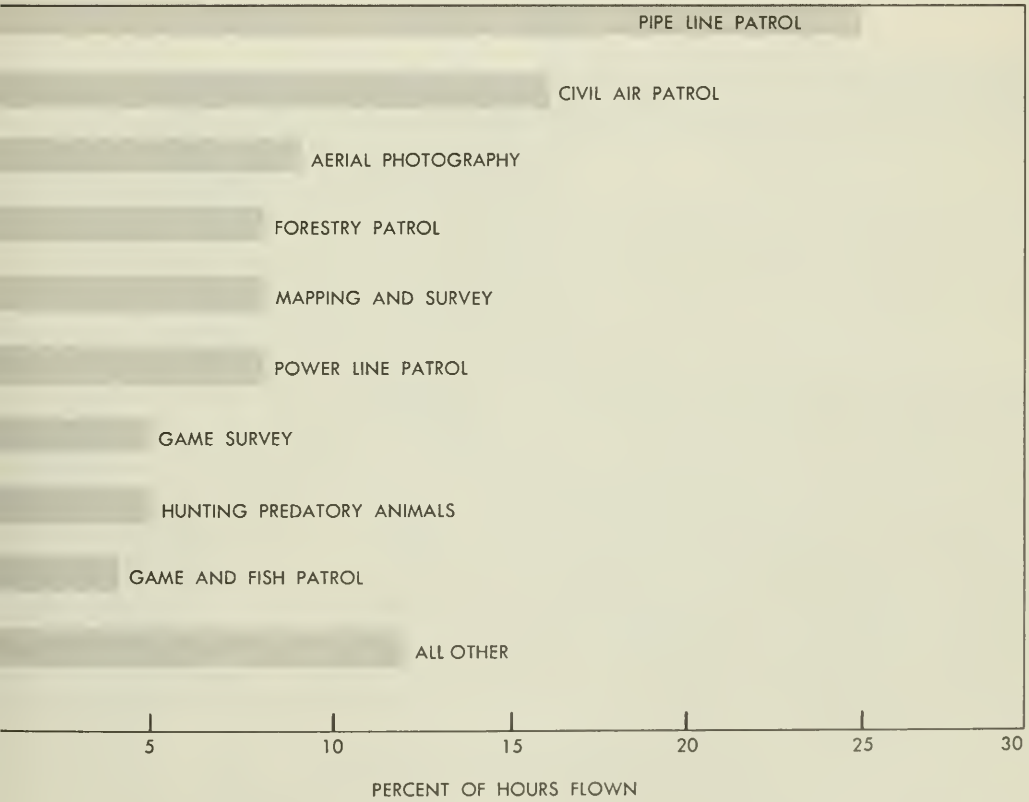


Transland AG–2, all-metal aerial application monoplane.

Courtesy of Aviation Week

Courtesy of Piper Aircraft Corporation

Piper Super Cub "150" widely used general utility aircraft.



Civil Aeronautics Administration, Annual Survey of Aircraft Use

Major Types of Patrol, Survey and other Industrial flying in 1954.

THE CIVIL AIR PATROL [18]

The Civil Air Patrol (CAP) accounts for the largest single segment of patrol flying, with the single exception of pipeline patrol. By itself the nature of the service rendered by this outstanding organization of private citizens puts it first in order of importance. The work of the Civil Air Patrol is closely bound up with the security of the United States. Through its nationwide organization and its grass-roots aviation work, the CAP functions as a vital instrument of American air power, ever ready for large-scale emergency effort on behalf of the local community or the nation itself.

One week prior to the attack on Pearl Harbor, President Roosevelt issued an executive order establishing the Civil Air Patrol. This action climaxed the efforts of civilian aviation enthusiasts to found an organization through which they could contribute to the nation their time, services, and aircraft. Gill Robb Wilson, noted aviation writer and publisher, and Guy Gannett, the late newspaper publisher and broadcasting executive, were the most active and influential sponsors. The coming of the war underscored the need for civilian assistance in the aviation field. Soon the CAP was made a branch of the Office of Civilian Defense under Mayor Fiorello La Guardia. It competently carried out its first major assignment in the critical early months of

U. S. Air Force Photo

Civil Air Patrol aircraft of the Maryland Wing Civil Air Patrol participating in an air defense exercise designed to train members of the Modonna, Maryland Ground Observer Corps.

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[18] Material on the Civil Air Patrol is based upon *General Training Bulletin*, Exercise 17, entitled "Civil Air Patrol," published for the Air Reserve Training Program by the Air Command and Staff College, Air University, Maxwell AFB, Ala., 1957.

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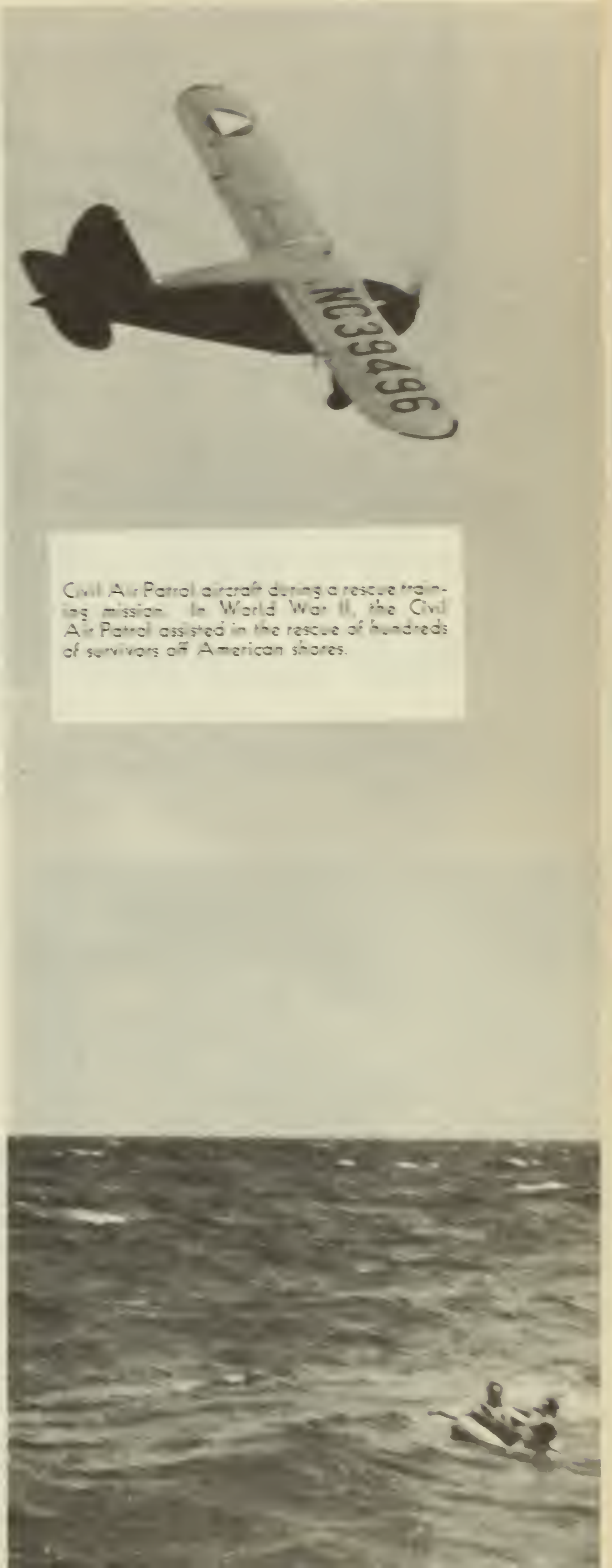

Civil Air Patrol aircraft during a rescue training mission. In World War II, the Civil Air Patrol assisted in the rescue of hundreds of survivors off American shores.

U. S. Air Force Photo

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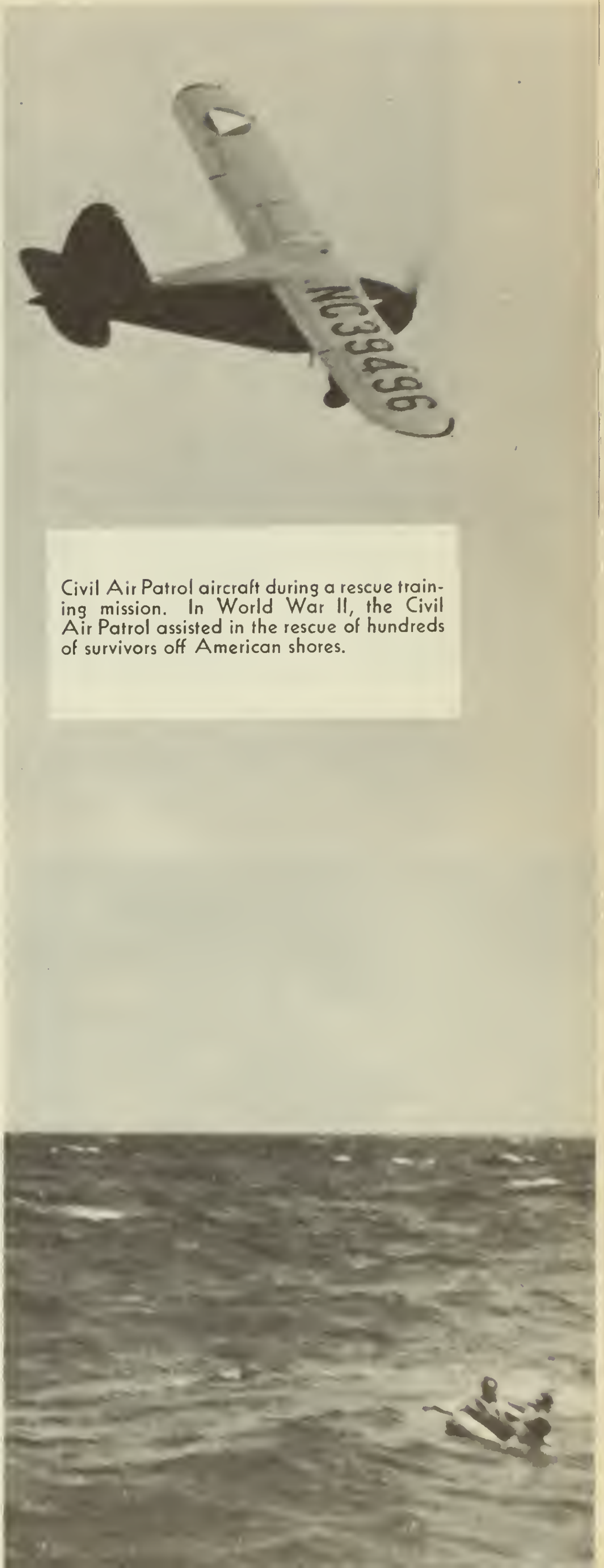
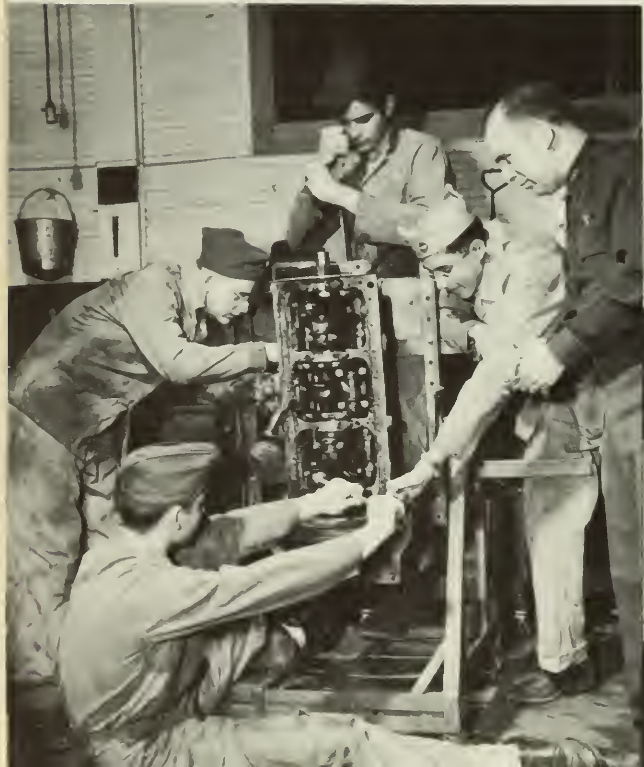


Civil Air Patrol aircraft during a rescue training mission. In World War II, the Civil Air Patrol assisted in the rescue of hundreds of survivors off American shores.

U. S. Air Force Photo

Civil Air Patrol Certificates of Award Ceremony. Shortly after the close of World War II Wing Commanders of the Civil Air Patrol gathered at the Pentagon in Washington, D. C. where they were awarded certificates of appreciation by General Carl Spaatz, Army Air Forces, in recognition of the outstanding war services of the Civil Air Patrol. Above a group of the Commanders present are pictured with General Spaatz. They are left to right: Lt. Col. G. A. DaCosta, Springfield, Ill.; Lt. Col. Walker Winslow, Indianapolis, Indiana; Gen. Spaatz; Lt. Col. R. H. Baker, Detroit, Michigan; Lt. Col. G. A. Stone, Columbus, Ohio, and Lt. Col. J. F. Stratton, Milwaukee, Wisconsin.

U. S. Air Force Photo

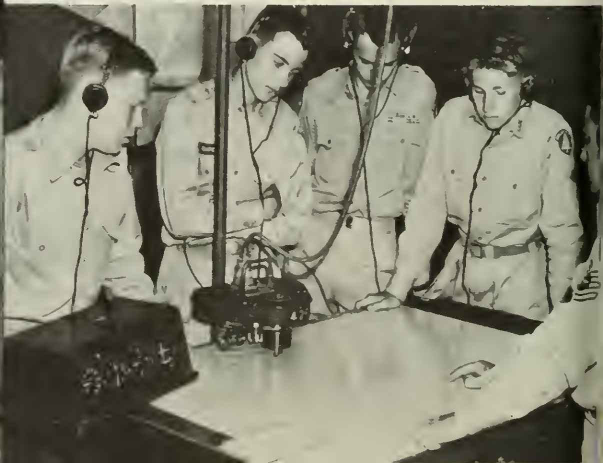


U. S. Air Force Photo

Providing aviation education to its younger members is a major responsibility of the Civil Air Patrol. These young CAP Cadets are being instructed in aircraft engine maintenance.

Group of Civil Air Patrol Cadets receiving navigation instruction at the Link Trainer Department at Goodfellow Air Force Base, Texas.

U. S. Air Force Photo



screening operations, and conducted radar training flights. As if this were not enough, it also gave basic aviation training to 40,000 cadets.

Civil aviators in this quasi-military organization flew over 20,000 miles a day to carry mail, critical repair parts, and other priority wartime cargo.

After the war was over, the Army Air Force strongly recommended that the Civil Air Patrol be kept intact as an organization. Congress recognized the potential of this civilian adjunct to American military air power, and chartered it as a non-profit organization in July 1946.

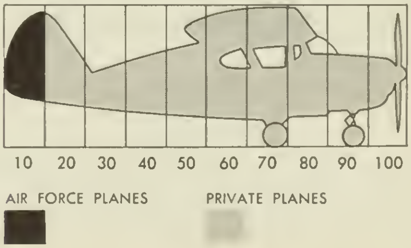
The charter emphasized the role of the Civil Air Patrol as an organization which would seek to channel the energies of private citizens interested in aviation and direct them toward national goals. These goals were "the development of aviation" and "the maintenance of air supremacy." Through the directed effort and specific example of its members, CAP was to foster the growth of civil aviation in local communities, and provide "an organization of private citizens with adequate facilities to assist in meeting local and national emergencies." The charter also called upon CAP to provide aviation education, especially to its younger members.[14]

Two years after giving the CAP its charter, Congress formally made the organization a volunteer auxiliary of the United States Air Force. It also authorized the Air Force to resume the type of assistance given to CAP during the Second World War In this way, the CAP was again able to obtain from the military establishment some light planes, fuel, lubricants, and surplus equipment needed to carry out its mission. Military assistance, however, was not limited to material aid, for Air Force personnel were now assigned in a liaison capacity to the National Headquarters of the CAP at Bolling Air Force Base, D. C., and also to the headquarters of each of the 52 CAP wings.

ACCOMPLISHMENTS. Although the largest proportion of its flying time is devoted to flight orientation and training of its cadets, CAP performs many other valuable services which directly benefit the community and the nation. Most of these fall in the category of patrol and survey activity.

The Civil Air Patrol annually flies about half or more of all the search and rescue missions performed by Air Rescue Service in continental United States. Besides flying searches for the Air Force, the CAP runs blood-lift missions, provides emergency airlift for the sick and injured, carries out tracking missions for the ground observer corps, and reports the spotting of forest fires. This work is done largely through the use of privately owned planes, for only about 10 percent of CAP aircraft are contributed by the Air Force.

Furthermore, each CAP wing cooperates with Civil Defense units in its area in coordinating and carrying out defense and search functions. In these tasks, the CAP's communications channels play an important role. The organization has over 12,000 fixed and mobile stations to fill its needs.



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[14] Any United States citizen, or alien who has filed first papers for citizenship, and who is 18 years of age or over is eligible for senior membership in the Civil Air Patrol. Any United States citizen, or alien who has filed first papers for citizenship, who is fourteen years of age may become a cadet member of Civil Air Patrol. Membership in CAP is not considered as a military service and does not exempt the member from service in the armed forces. Upon completion of the prescribed training program and attainment of the CAP Certificate of Proficiency, Civil Air Patrol members are given priorities for enlistment in the United States Air Force, Air Force Reserve, Air Force ROTC, and Air National Guard.

PIPE, POWER, AND TELEPHONE LINE PATROL

The largest segment of patrol and survey flying is the monitoring of the cross-country portion of public utility properties. The objective of these patrols is nothing less than to maintain continuous operation of pipe, power, and telephone lines. In terms of distance, public utility patrol aircraft fly about 17 million aircraft miles a year.

Aircraft are ideally suited for this type of work because an aerial observer is capable of inspecting a given length of pipeline in a fraction of the time required by walking patrols. If the observer detects discoloration of the earth or withering of the foliage—indications of a break in a gas line—he immediately directs maintenance crews to the affected area by radio. Since this type of inspection requires low-level flying, the CAA has issued waivers in some cases to permit such operations at an altitude of 50 feet with visibility of one-eighth of a mile.

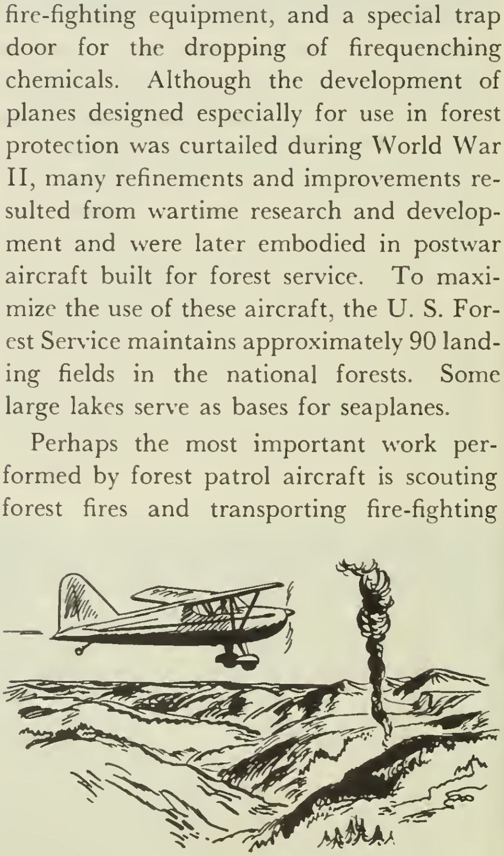
Air vehicles also provide an efficient and rapid means of checking power lines and telephone trunk lines for cable breaks, damage to poles, transformers and other equipment, and accumulation of ice on lines. The helicopter has demonstrated a degree of performance superior to that of fixed-wing aircraft in patrol and survey work. Two-thirds of the power and pipeline patrolling is done by operators in the southern states, and one-fifth in the north central states.

FORESTRY PATROL

Fire is a constant menace to the 615 million acres of forestland in the United States. Annually 50,000 fires destroy much of this valuable natural resource. The airplane was first used for forestry patrol in 1919, with the United States Army financing almost the entire project that year. Seven Army pilots made regular daily flights over the California national forests and reported 422 fires in a five-month period. Not until 1928 did Congress regularly appropriate funds for air patrol work by the United States Forest Service. Since that time aerial patrol of forests has been generally conducted by commercial aviation organizations on a contract basis. By 1930 aerial patrol aircraft were hired by the states of Oregon, Idaho, Washington, Montana, California, Arizona, New Mexico, Nevada, Colorado, Utah, Michigan, Minnesota, and Wisconsin.

In 1938 the United States Forest Service purchased for its own use an experimental aircraft which featured an adjustable pitch propeller for low flying efficiency, a special bombsight for accurate dropping of food and fire-fighting equipment, and a special trap door for the dropping of firequenching chemicals. Although the development of planes designed especially for use in forest protection was curtailed during World War II, many refinements and improvements resulted from wartime research and development and were later embodied in postwar aircraft built for forest service. To maximize the use of these aircraft, the U. S. Forest Service maintains approximately 90 landing fields in the national forests. Some large lakes serve as bases for seaplanes.

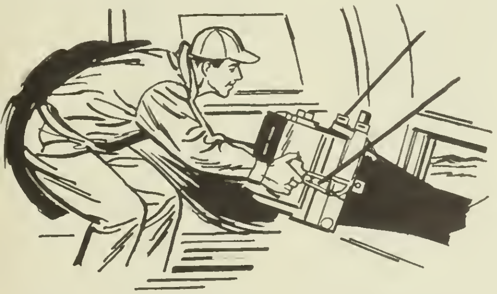
Perhaps the most important work performed by forest patrol aircraft is scouting forest fires and transporting fire-fighting



personnel and supplies. A skilled aerial scout can determine quickly the intensity, direction of burning, location, damage, and the geographical extent of the fire. From a vantage point high in the air, he is usually able to spot natural barriers to the spread of the fire and determine the most practical means of deploying ground crews.

The invaluable work of aerial patrol and fire scouting is often expedited by means of aerial photography. Photographs taken from the air are quickly developed and delivered to the firecrew. They provide excellent information on terrain, streams, trails, roads, and other ground features close to the fire. In Montana an observer in a patrol plane equipped with a camera and printing outfit reportedly photographed a forest fire, developed an 8 x 10 picture, and dropped it to a waiting receiver on the ground—all in 18 minutes!

Other important functions performed by means of aerial patrol and survey over forested areas include the inspection and appraisal of timber for commercial purposes. Insect damage can be spotted through discoloration or defoliation of trees. Forest patrol activity is naturally greatest in the southern and western states.



Aerial Photography and Mapping and Survey

These two functions represent rather specialized uses of aircraft wherein the camera is substituted for the human eye of an observer to provide a permanent record of an area. Aerial photographs and surveys fill a variety of needs and are especially useful when views of large areas of the earth's surface are required. They are helpful in plant site selection, determination of industrial land use, flood control. fire-fighting, and hydro-electric and irrigation projects. Aerial photographs and surveys are also used to advantage in projection of transportation and pipeline routes, real estate development and sales, tax assessment studies, and city planning and traffic studies.

A comparison of survey methods employed in official topographic mapping of political units will give us some conception of the savings in time and energy made possible by the airplane. Men working on the earth's surface have to use tedious and time-consuming procedures to map a given area; they run the risk, furthermore, of making serious errors. From the air, however, they can map the same area in a fraction of the time otherwise required, and with highly accurate results. The U. S. Geological Survey reported, that by utilizing aircraft equipped with special cameras, it was able to map the entire continental United States within a period of two years. Compare this with the estimated 50 years that would be required to map the State of Pennsylvania by the plane table and level method.

Prospectors seeking mineral deposits sometimes employ color photography from the air to aid them in their systematic search. The color of rock formations, soil, and outcroppings of ore provide indications of the presence of various mineral deposits. Similarly, soil surveys employing color aerial photography often indicate to the soil scientist the quality of the soil in a given area.

Aerial photography also serves less scientific, if equally commercial, purposes. Almost all newspapers and many magazines frequently print aerial photos to illustrate news accounts of the havoc wrought by floods, hurricanes, fires, and other natural disasters.

Wildlife Conservation and Herding Livestock

There are many ways in which aircraft help local, state, and Federal officials to control and conserve animal life in our forests and on open ranges. They are used to introduce valuable animals to certain areas, to locate resource damage, to count wildlife population, and to stock lakes with fish.

The airplane and helicopter perform important services in the grazing industry by providing ground personnel with information about range conditions. Aerial services aid in the location and eradication of predatory animals preying on stock. Aircraft can save cattle or game in large numbers by making emergency food drops. This happened, for example, when a recent midwestern blizzard left many cattle stranded without food Operation "Hay-lift," which was organize with the help of the United States Air Fce, sent aircraft to the rescue, and thousan of bales of hay were dropped on the range

Other Patrl and Industrial Aviation Activities

The accomanying table provides information on a iscellany of minor patrol and industrial acvities in the general aviation field. It al furnishes a convenient reference list compassing all activities of this nature.

Civil Aeronautics Adm stration Annual Survey of Aircraft Use

HOURS FLOWN IN PATROL, SURVEY, AND OTHR INDUSTRIAL ACTIVITIES
Continental United States, 1954 nd 1953

Activity	54		1953	
	Hours flown	Percent of total	Hours flown	Percent of total
Pipe line patrol	145, 10	25	107, 300	30
Civil air patrol	94, 00	16	([1])	....
Aerial photography	49, 3	9	35, 700	10
Forestry patrol	46, 0	8	30, 700	9
Mapping and survey	45, 50	8	34, 600	10
Power line patrol	43, 6	8	31, 400	9
Game survey	31, 10	5	19, 800	9
Hunting predatory animals	29, 2	5	24, 000	7
Game and fish patrol	24, 90	4	20, 100	6
Sign towing	11, 50	2	9, 200	3
Checking livestock	11, 00	2	6, 400	2
Hunting lost persons	10, 10	2	8, 100	2
Herding livestock	4, 30	1	1, 400	*
Border patrol	4, 30	1	8, 800	3
Highway patrol	3, 40	1	2, 100	1
Fence patrol	3, 40	1	1, 100	*
Glider towing	3, 40	1	1, 100	*
Dropping leaflets	2, 40	*	1, 400	*
Hunting eagles	1, 90	*	1, 400	*
Aerial advertising—Loudspeaker	1, 90	*	2, 100	1
Herding wild game	1, 40	*	1, 400	*
Skywriting	1, 40	*	1, 100	*
Truck line patrol	1, 40	*	1, 400	*
Aerial advertising—Neon lights	1, 00	*	400	*
Telephone line patrol	1, 00	*	1, 400	*
Log patrol	50	*	400	*
Total, all types	573, 00	100	352, 800	100

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[1] Civil Air Patrol flying was not reported separately in 1953 b was included with experimental test flying. Reportedly, CAP flying accounted for about 85,000 hours 1953

Source: CAA Off al Aviation Activities.

Loading operations of a Slick Airways non-scheduled cargo transport.

GENERAL AVIATION TRANSPORTATION FOR HIRE

Operating outside the scheduled common carrier field are several types of irregular air carriers which provide passenger and cargo transportation on a "for hire" basis—air taxi services, fixed-base operators flying special charter or contract flights, and non-scheduled airlines.

Among these groups, the non-scheduled airlines or "non-skeds" are commercially the most important, both in the United States and elsewhere. Some of them are several years older than the scheduled airlines. Although unable to publish or advertise fixed times of departure and arrival, they find customers who are attracted by the dual inducement of speed and low fares or low freight rates. Not infrequently these non-scheduled airlines make arrangements with ticket agencies to solicit business.

Exemplifying the irregularity of service which gives irregular carriers their name is the following intinerary of a typical cargo plane whose crew knew its first destination only. The airplane left Newark, New Jersey, for Mexico City loaded with typewriters, radios, and textiles. At Mexico City the crew took on a load of bananas for New York. At New York they were ordered to fly to Dublin with a load of mixed cargo. In Dublin they found six race horses waiting to be flown to Los Angeles. After delivering these animals, they loaded 18,000 pounds of fresh fruit for Alaska. There they took aboard gold and iced salmon destined for Washington and New York. Back in New York they found a shipment of radios and an automobile for delivery to Venezuela. In a period of two weeks, the airplane had visited three countries and one territory without once being at its home base in St. Joseph, Missouri.[15]

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[15] National Aviation Education Council, *Flying Cargo* (Washington, 1956).

and on open ranges. They are used to introduce valuable animals to certain areas, to locate resource damage, to count wildlife population, and to stock lakes with fish.

The airplane and helicopter perform important services in the grazing industry by providing ground personnel with information about range conditions. Aerial services aid in the location and eradication of predatory animals preying on stock. Aircraft can save cattle or game in large numbers by making emergency food drops. This happened, for example, when a recent midwestern blizzard left many cattle stranded without food. Operation "Hay-lift," which was organized with the help of the United States Air Force, sent aircraft to the rescue, and thousands of bales of hay were dropped on the ranges.

Other Patrol and Industrial Aviation Activities

The accompanying table provides information on a miscellany of minor patrol and industrial activities in the general aviation field. It also furnishes a convenient reference list encompassing all activities of this nature.

Civil Aeronautics Administration, Annual Survey of Aircraft Use

HOURS FLOWN IN PATROL, SURVEY, AND OTHER INDUSTRIAL ACTIVITIES

Continental United States, 1954 and 1953

Activity	1954		1953	
	Hours flown	Percent of total	Hours flown	Percent of total
Pipe line patrol	145, 100	25	107, 300	30
Civil air patrol	94, 000	16	(1)	....
Aerial photography	49, 300	9	35, 700	10
Forestry patrol	46, 000	8	30, 700	9
Mapping and survey	45, 500	8	34, 600	10
Power line patrol	43, 600	8	31, 400	9
Game survey	31, 100	5	19, 800	9
Hunting predatory animals	29, 200	5	24, 000	7
Game and fish patrol	24, 900	4	20. 100	6
Sign towing	11, 500	2	9, 200	3
Checking livestock	11, 000	2	6, 400	2
Hunting lost persons	10, 100	2	8, 100	2
Herding livestock	4, 300	1	1, 400	*
Border patrol	4, 300	1	8, 800	3
Highway patrol	3, 400	1	2, 100	1
Fence patrol	3, 400	1	1, 100	*
Glider towing	3, 400	1	1, 100	*
Dropping leaflets	2, 400	*	1, 400	*
Hunting eagles	1, 900	*	1, 400	*
Aerial advertising—Loudspeaker	1, 900	*	2, 100	1
Herding wild game	1, 400	*	1, 400	*
Skywriting	1, 400	*	1, 100	*
Truck line patrol	1, 400	*	1, 400	*
Aerial advertising—Neon lights	1, 000	*	400	*
Telephone line patrol	1, 000	*	1, 400	*
Log patrol	500	*	400	*
Total, all types	573, 000	100	352, 800	100

[1] Civil Air Patrol flying was not reported separately in 1953 but was included with experimental test flying. Reportedly, CAP flying accounted for about 85,000 hours in 1953.

Source: CAA Office of Aviation Safety, Survey of Industrial and Agricultural Aviation Activities.

Loading operations of a Slick Airways non-scheduled cargo transport.

General Aviation Transportation for Hire

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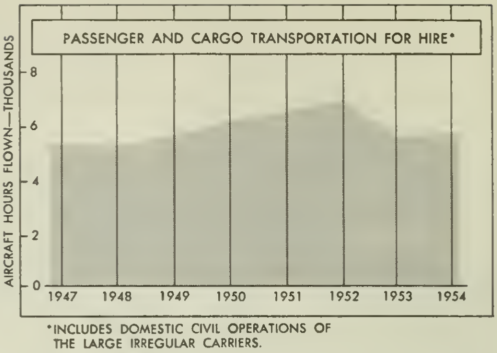
[15] National Aviation Education Council, *Flying Cargo* (Washington, 1956).

The non-scheduled airlines suffered a heavy drop in cargo business in 1955 when their freight ton-miles fell from 24.8 to 18.3 million. This drop came on the heels of a series of successive annual declines in the nonscheduled passenger and cargo business.

Most of the business of the non-skeds apparently went to the scheduled operators, since the total domestic air cargo ton-miles flown during 1955 increased considerably. Trends in the air cargo busines are depicted graphically below .



*INCLUDES DOMESTIC CIVIL OPERATIONS OF THE LARGE IRREGULAR CARRIERS.

Civil Aeronautics Administration, Survey of Aircraft Use

While the large irregular cargo business seems to be on the decline,[16] air taxi service is on the rise, despite its newness. Approximately 1,400 air taxi operators are spread throughout the United States. Air taxis are now available at almost every large airport. They transport films and newspapers, obtain spare parts, and provide quick connections with oceanliners, homes and offices, and the like.

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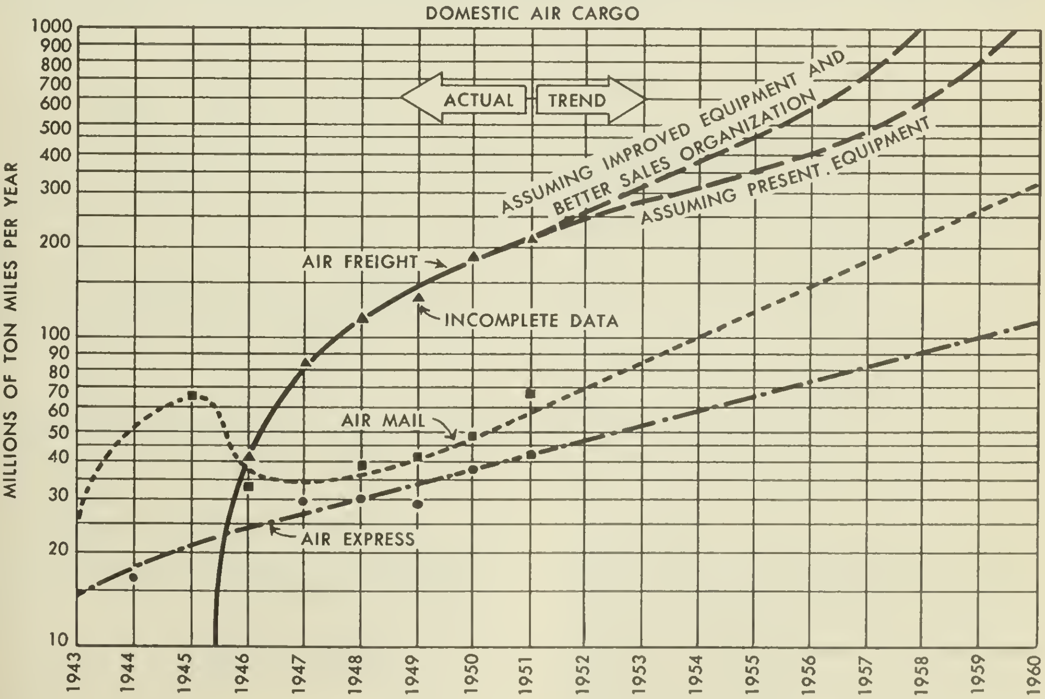
[16] The development of the larger non-skeds and their concerted but vain effort to receive trunkline certification from the CAB are described sympathetically in Robert Bendiner's, "The Rise and Fall of the Non-skeds," *The Reporter,* Vol. 16 (May 1957), pp. 29–34.

First express shipment by air, 1910. Cargo consisted of a bolt of silk which was flown from Dayton to Columbus, Ohio.

American Transport Association Photo

U. S. Air Force Photo

Lockheed Express used in air-taxi service in the early 1930's. The plane was flown by Colonel Roscoe Turner, world-famous pilot of the decade prior to World War II.



Air Cargo of the United States: Trends and Projections, 1943–60.

Courtesy of American Aviation

Speedy transportation of vital machine parts is so essential at harvest time in our great farm belt areas that small airport operators have standing agreements or contracts to procure parts from supply houses. They use small aircraft which can be landed on a field near the broken-down piece of equipment. A mere phone call to the aviation firm will bring a new part by the time the mechanic is ready to install it.

The airplane has also altered the distribution practices of newspapers and magazines, and accordingly has affected reading habits. Years ago, for example, the Boston and Providence newspapers were not available out on Cape Cod until a day or two after publication. There was no way to speed up delivery until an enterprising base operator at the Hyannis Airport contracted to fly in bundles of papers each day. The papers sold rapidly and were in great demand, especially during the tourist season. Papers from many towns are now regularly flown into the Cape Cod area and are readily sold at bonus prices.

In many parts of the country the airplane is used to speed up regular delivery of out-of-town newspapers. The *Salt Lake Tribune* uses air transportation to send copies of its regular edition to Yellowstone National Park. It also flies special election editions as far north as Idaho. *The Chicago Daily News* is flown to certain sections of Wisconsin and Michigan to people who want regular deliveries during the summer holiday season. Of course nationally important newspapers like *The New York Times* are flown to almost all cities in the United States.

From England newspapers are flown to Central Africa, India, and Australia. Though this is an expensive practice, many

UNITED STATES AIRCRAFT ENGAGED IN AIR TRANSPORTATION *

Active operators	Douglas					Curtiss	Lockheed		Miscellaneous	Total
	DC–6	DC–6B	DC–4	DC–3	DC–2	C–46	L–1049	L–749		
4	1	......	2	3	......	6	......	......	......	12
10	......	......	......	1	......	46	......	1	......	48
2	......	......	......	3	......	4	......	......	......	7
21	......	2	24	12	1	14	......	......	......	53
3	......	......	1	2	......	1	......	......	[c] 1	5
0	......	......	......	......	......	......	......	......	......	0
5	......	......	21	......	......	3	[b] 4	......	[a] 3	31
Total... 44	1	2	48	21	1	74	4	1	4	158

Courtesy of American Aviation

Note.—Data compiled from currently effective Operations Specifications—Aircraft Identification—Form 518–A. Includes operators certificated under CAR 45, in addition to CAR 42. Regional distribution of aircraft is based on location of the principal maintenance base for the particular aircraft involved.

*This does not include the irregular air carrier aircraft below 12,500 lbs.

[a] 3, SA–16A (Grumman Albatross).

[b] 3, L–1049D; 1, L–1049E.

[c] 1, B–18.

readers nevertheless are willing to pay the price. To overcome this obstacle, specially prepared airmail editions of some papers are now published. Their reduced size and weight permit corresponding reductions in price. *The Manchester Guardian Weekly*, for instance, issues a special international airmail edition which sells in the United States for 15 cents and is available to students at even lower group rates. In the U. S. S. R. jet airliners make daily runs from Moscow and Leningrad to all key cities for the express purpose of carrying newspaper plates of the latest issues of *Pravda* and *Izvestia.* Thus on the same day Soviet citizens, unlike their Czarist forebears, can read the same newspaper with the same government line throughout the length and breadth of the empire.

During 1954 the irregular carriers of the United States flew 14 million miles more than all the scheduled all-cargo operators, the local service scheduled airlines, the scheduled territorial airlines of Hawaii and Alaska, and the scheduled helicopter services put together.[17]

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[17] CAA, *AWBI*, p. 21.

INSTRUCTIONAL FLYING

Instructional flying may be defined as all dual and solo flying under the supervision of an instructor. Its annual volume of 1.3 million hours approximately equals the combined total for aerial application and transportation for hire. Based on a conservative estimate of $10 charged per hour of flying instruction ($12 for dual and $9 for solo), flight instruction represents an annual outlay of approximately $13 million by flying enthusiasts.

The hours consumed in instructional flying amounted to 14 percent of the general aviation total for the continental United States during 1954. The figure varied moderately from region to region, ranging from 11 percent in the southern states to 16 percent in the northeastern and north central states. Small single-engined aircraft of 65 horsepower and less were the work horses of the flight schools, flying 671,000 hours or more than one-half the instructional aggregate.

That the 2,000 or more flight and ground schools in operation constitute an invaluable asset to national defense has been proved by the history of instructional flying in recent years. With the decline in the number of World War II-trained fliers, there is today again a growing need for the services of the civilian instructional flying schools.

Civil flight training has been the most volatile type of general aviation activity. Its abrupt rises and falls have been closely keyed to the military program, with a rapid growth during World War II under the civilian pilot training program, and an even larger expansion following the war under the stimulus of the G. I. Bill of Rights flight training program. From 1947 to 1953, however, instructional flying experienced a steady drop as the Veterans Administration brought the G. I. program under more stringent regulation.

During the six-year period, while instructional flying fell off in number of hours, other general aviation activities were gradually gaining. But in spite of such dips, flight training seems likely to continue as a sizeable activity since it is the basic foundation for all types of general aviation operations. Without a constantly available and substantial supply of trained fliers to draw upon for its needs, aviation cannot remain dynamic.

In recognition of this, the CAA has inaugurated a program of aviation education which is designed to stimulate interest in aviation among high school students. This program, now under way, is attempting to capture the interest of youth at an early age and to keep it alive at later age and grade levels. The specific course offered at present, *Aviation in the Modern World,* is exploratory in nature and provides interesting and valuable vocational guidance to students enrolled in the Industrial Arts or Vocational Education programs of high schools. Since qualified teachers will be needed to implement the program, the CAA is also trying to help teacher-training institutions to estabisl aviation curricula.

PLEASURE FLYING

Pleasure flying is the use of general aviation aircraft for purposes of recreation or personal convenience. Included in the pleasure category are local and cross-country flights connected with such diverse activities as sightseeing, touring, hunting, fishing, and other forms of sport. And, of course, there are those flights which offer nothing other than the sheer enjoyment of being in the air and handling an airplane.

Second only to business flying in volume, pleasure flying accounts for one-fifth to one-quarter of the hours logged in the field of general aviation. Over one-half the nation's non-airline planes are employed to some extent for pleasure. Naturally, the single-engined type lends itself best to this function. The multi-engined aircraft plays a small role at best in pleasure flying. A forecast of future growth trends in this sector is shown below.

Student being helped with parachute by his glider pilot instructor. Not only is glider flying becoming a popular sport, but is also an excellent means for obtaining an understanding of the aerodynamics of powered flight.

U. S. Air Force Photo

Pleasure flying represents about one-fifth of all general aviation flying. Private ownership of pleasure aircraft is rapidly growing in the United States.

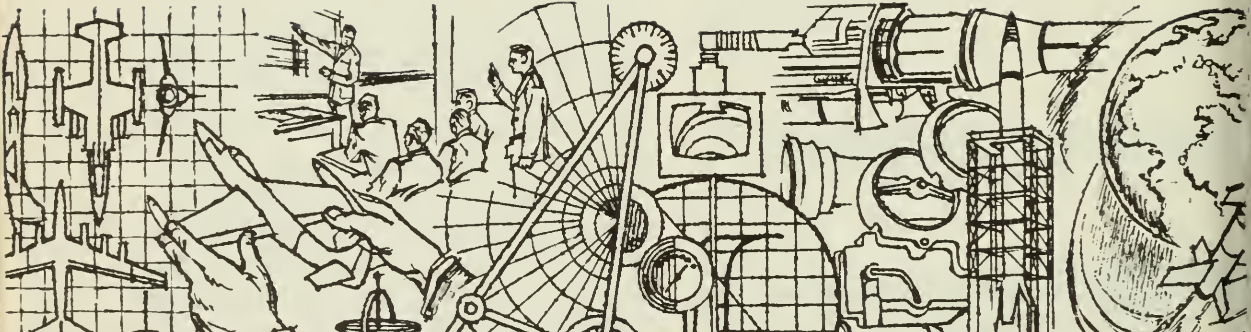
GENERAL AVIATION FLYING: SUMMARY AND CONCLUSION

We have seen that in recent decades the commercial advantages of the airplane have been conclusively demonstrated in a variety of activities outside of the scheduled airline field. The airplane now performs a host of functions related to the successful daily operation of the economic and social order. In its use by corporations and individual business men, farmers, and ranchers, aerial application specialists, irregular carriers and operators involved in commercial patrol, survey, and other enterprises, it serves private ends but at the same time works for the general welfare. It also performs specific public service functions in Civil Air Patrol work, conservation and game surveys, geological surveys, forest patrols, border patrols, and community insecticide spraying campaigns.

The general aviation airplane also serves directly and indirectly in the defense of the nation whenever the need arises. Its worth as a defense tool is indicated in the following statement by Donald W. Nyrop, Administrator of the Civil Aeronautics Administration at the time of the Korean War: ". . . Our Aviation Development Advisory Committee . . . has stressed the great variety of contributions which non-airline flying makes to our national defense and welfare. . . . We know, for example, that food is a weapon, and that the 5,000 planes doing agricultural flying conserve hundreds of millions worth of crops. We know that the more than 2,000 flight and ground schools may be needed for training purposes if the armed forces' air personnel requirements increase greatly. We know that the use of small planes for pipeline patrol, ambulance service, and countless other utilitarian purposes has a place in a defense economy just as much as in peacetime. . . ."

There is no doubt that the tens of thousands of general aviation aircraft would be an invaluable national resource in an emergency. The 2,100 planes of the multi-engined general aviation business fleet (a force larger than the scheduled airline fleet) could be employed in numerous transportation capacities; and the many lighter general aviation aircraft would be at least as useful because of their ability to land in small areas under difficult conditions. In the event of a major nuclear war general aviation aircraft could render critical aid to devastated urban areas, and help to restore their links with the outside world.

In war or in peace general aviation contributes significantly to the effective functioning of the community and the nation.

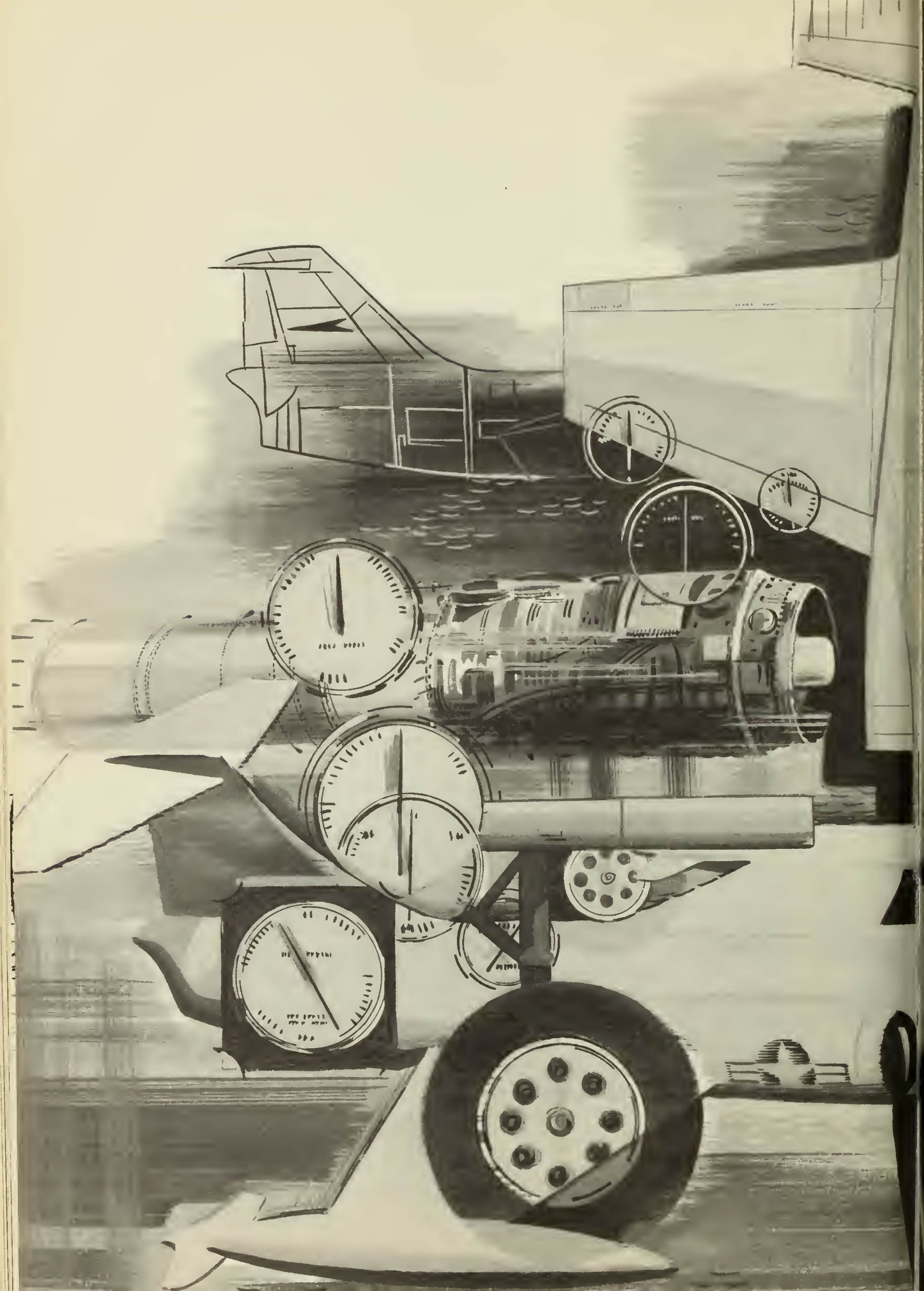


PART TWO

AIR VEHICLES AND PRINCIPLES OF FLIGHT

In Part One we became familiar with the pyramidal structure of a nation's air power. From our initial discussion of the fundamental factors or elements of air power—both primary and secondary—we saw that at the apex of the nation's air power pyramid is its military air force. Chapters 2 through 6 demonstrated how the air force-in-being depends upon and exists as a result of the nation's efforts. These efforts are centered particularly in research and development, aircraft and missile construction, and the civil aviation complex of airways, airlines, and general aviation. Rising from the foundations provided by these elements is the nation's military air force. The supreme embodiment of America's air power is, of course, the USAF. In order to better understand the Air Force itself, however, it is necessary to gain some conception of the individual vehicles of the Air Force and how they are operated.

In Part Two we shall discuss the functions and parts of an air vehicle, principles of flight, and methods of propulsion and navigation. Finally, we shall take a look at what the future may hold in the way of air and space vehicles.



PART 2

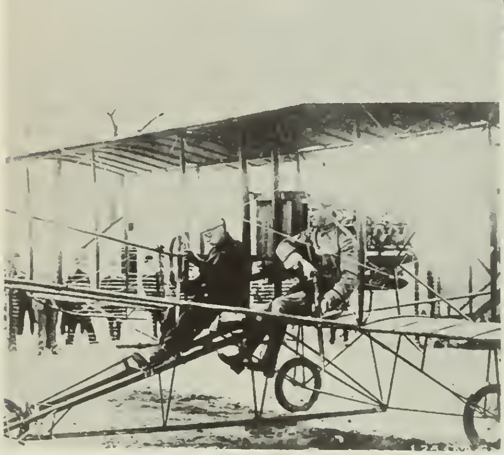
CHAPTER 7

The Elements of an Aircraft

There are six functions represented in the design and structure of any useful flying vehicle: First, it must have some means of *carrying* something other than itself—a weapon, a passenger, a cargo, or something else. Second, it must have a means of levitation, a device which will provide a *lift* force sufficient to take it up and keep it up without direct support from the ground. Third, it must have a means of *propulsion* to move it forward. Fourth, it must have a system to *control* its attitude, position, speed, and so on. Fifth, it must have *navigation* devices to assure that it arrives at its intended destination. And sixth, it must have some ground-handling apparatus to permit ease of take off, landing, and moving about on the ground. This is usually *a landing gear.*

In the airliner that lands at your municipal airport, these elements appear in their most familiar form—a fuselage for carrying, wings for lift, engines with propellers for propulsion, conventional compasses and other instruments for navigation, wheels for landing—but these structures were not always like this, and need not be in the future.

▲ Orville Wright flying the Wright "Flyer" at Fort Myer, Va., in 1908. The plane used skids for landings and take-offs and was propelled by a 35 horsepower engine.



◀ Curtiss pusher biplane at Sheepshead Bay, N. Y., 1910. Charles F. Willard is at the controls. Beside him, Maj. J. E. Fickal is holding the first rifle ever fired from an airplane. Note the plane's tricycle landing gear.

The purpose is to clarify the essential functions and to show the diversity of possible ways of achieving them. In later chapters, we will discuss in greater detail the more common approaches to building these elements into an aircraft.

In this chapter, many variations of form for these six essential functions will be illustrated, and further possibilities discussed.[1]

CARRYING SPACE

The major carrying space of a flying vehicle is usually in the fuselage. Typically, the fuselage is designed to contain the pilot and other crew members, the cargo, the passengers, the radios, the navigational devices, weapons and weapon-aiming systems, cameras, and perhaps some or all of the fuel.

However, in many aircraft, fuel is contained in wing tanks, or in tip tanks, or in auxiliary tanks slung below the fuselage. Weapons may be mounted inside or under the wings, or in various kinds of pods.

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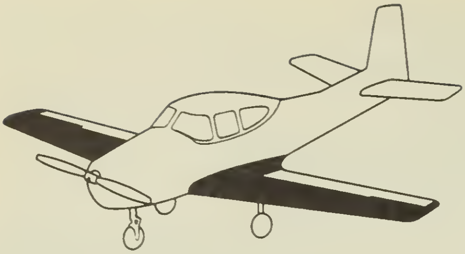
[1] Nearly all modern aircraft have two additional systems. One provides *communication* among persons within the aircraft, and between them and the ground or other aircraft. The other is called the *energy distribution system* and provides the electrical or hydraulic power to operate the other systems.

Paratroopers boarding a C–123. This aircraft can carry 60 fully equipped combat troops, or can be converted to carry more than 50 stretcher patients and attendants.

Cargo compartment in an Air Force C–124 "Globemaster." With 10,000 cubic feet of usable cargo space, the C–124 easily handles the "Snark" missile being loaded for shipment. The compartment can be converted into a two-decked carrier for over 200 troops.

Aptly named the "Workhorse," the Army's H–21 elicopter can carry 20 combat troops, cross-country ehicles or guns on tow cables beneath its fuselage. ere an H–21 is carrying a quarter-ton jeep during training mission.

An Air Force C–97 transport being loaded through large doors in its tail section. Its 60-foot-long cargo deck can accommodate three fully-loaded 1½-ton trucks or 134 troops and their equipment.



LIFT

The second essential element is a device or system for raising the vehicle off the ground. The earliest practical aircraft used lighter-than-air gases to achieve levitation. This is still the most efficient, practical source of pure lift, for the balloon actually uses the weight of the normal atmosphere to float the aircraft off the ground.

It is commonly thought that no expenditure of energy is necessary to achieve lift with a balloon. This is incorrect, for the lift force must come from somewhere. In fact, the total amount of work involved in inflating the balloon with lighter-than-air gas is about the same as the total lifting potential of the inflated balloon. However, the gas-generating machinery and the pumps for inflating the balloon can be located on the ground and not carried in the aircraft. This is a tremendous advantage.

To descend, lighter-than-air vehicles must either release gas or acquire weight. The former procedure is, of course, wasteful; the latter is difficult but not impossible. For example, certain dirigibles acquired some weight by condensing the water vapor from their engine exhausts.

If it were not for their great bulk and their vulnerability to attack and to the forces of nature, bags or tanks of lighter-than-air gases would be very attractive to the aeronautical designers as a source of lift. And indeed, they still have their uses in the Navy blimps used as radar pickets and search vehicles.

We are used to thinking of lighter-than-air craft as slow. Actually, there is no reason why they could not be made to fly at very high speeds. But they are necessarily bulky, for it takes a great volume of helium (the most commonly used gas) to lift any appreciable weight. They are therefore unwieldy and make good targets. While the wing is certainly more efficient and economical at

U. S. Navy Photo of Goodyear Airship

This U. S. Navy ZS2G-1 Airship uses 650,000 cubic feet of helium for lift.

U. S. Air Force Photo

One of the extra-curricular activities for cadets at the Air Force Academy is the Cadet Soaring Club. The Club has both high performance sailplanes and two-place training gliders like the one shown here.

An Air Force high altitude meteorological balloon inflated with hydrogen ready for launching. Hydrogen has the greatest lifting power of all gases, but is highly explosive when mixed with oxygen and must be handled with extreme care.

U. S. Air Force Photo

U. S. Air Force Photo

Goppingen "Minimoa" sailplanes have reached altitudes in excess of 40,000 feet.

present, it would be unwise to completely forget the light gases as a source of lift for high-performance aircraft. Someday we may learn to use them in a new, unimagined type of vehicle.

Another source of lift, and one widely used since the earliest days of aviation is the natural movement of air in the atmosphere. A leaf flying on the wind is the simplest example, and a kite is very similar. The sailplane, too, derives its lift and forward motion entirely from air movement and its own movement in the air. The sailplane pilot, once off the ground, uses his knowledge of meteorology [3] to find thermals or other updrafts of air. He flies in an updraft until it lifts him to sufficient altitude to glide to the next updraft, which lifts him again, and so on. This technique of flight is known as *soaring,* and is today quite a popular sport here as well as abroad. Thermals or other updrafts may be used as a source of lift for powered aircraft, too, and can be of great assistance in gaining altitude with a minimum of fuel consumption.

Though flight is entirely possible without any engine at all, unpowered aircraft are inevitably dependent upon weather conditions and other factors which make them less reliable than can be tolerated for most practical purposes. For this reason, all but a small percentage of the actual flying done today is in powered vehicles.

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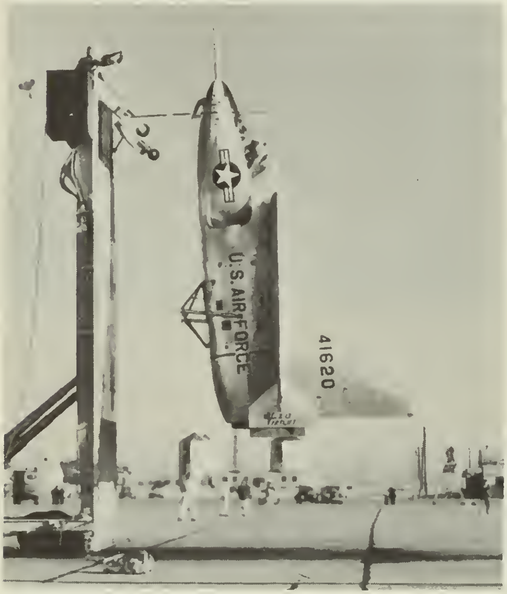
[3] *Meteorology* is the science of weather and the dynamic processes of the atmosphere.

Modern engines have now been developed which can produce more thrust than the total weight of the vehicle and its normal load. It is therefore possible to use the engine alone as a source of lift force. The Air Force's "Vertijet" rises straight up on the blast of its single jet engine and then flies like a conventional jet aircraft.

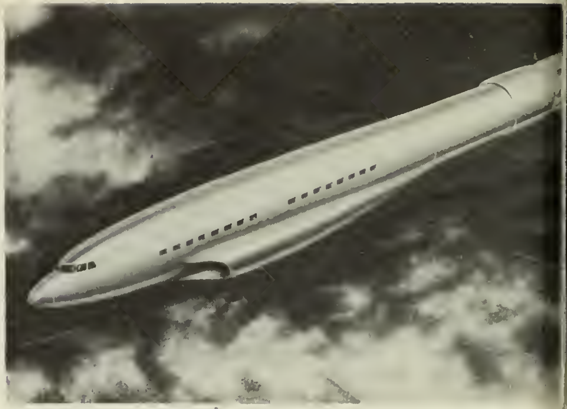


U. S. Air Force Photo

The Air Force X–13 "Vertijet" rises solely on the thrust from its jet engine. A highly mobile ground service trailer serves as the only runway it needs.

Nor is this all. There is the Lippisch aerodyne, an experimental device which has no wings and depends solely on down-blasts of air for its lift forces. Another experimental plane, the Coanda "lenticular aerodyne," has a disk-shaped wing and a powerplant with no moving parts.

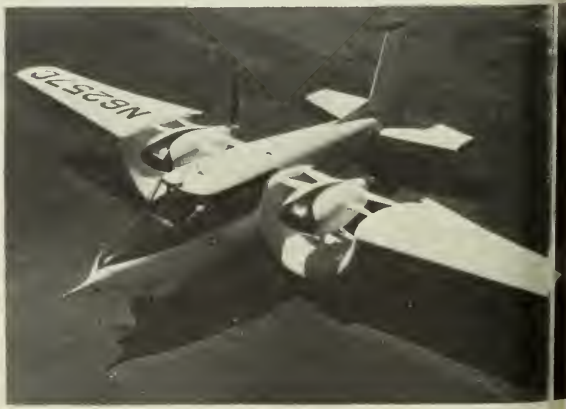
What the future may hold, we do not know. Perhaps levitation will be achieved by some new and startlingly different principle such as electrostatics or electrodynamics, or even, perhaps, by antigravitational devices. Several scientists have seriously proposed that negative gravitational matter may exist and they point to certain anomalies in various existing theories as possible evidence.



Courtesy of Collins Radio Corporatio

Artist conception of the proposed "Aerodyne" airliner developed by Dr. Alexander Lippish. This wingless aircraft will take off and land vertically, hover like a helicopter, and cruise like an airliner.

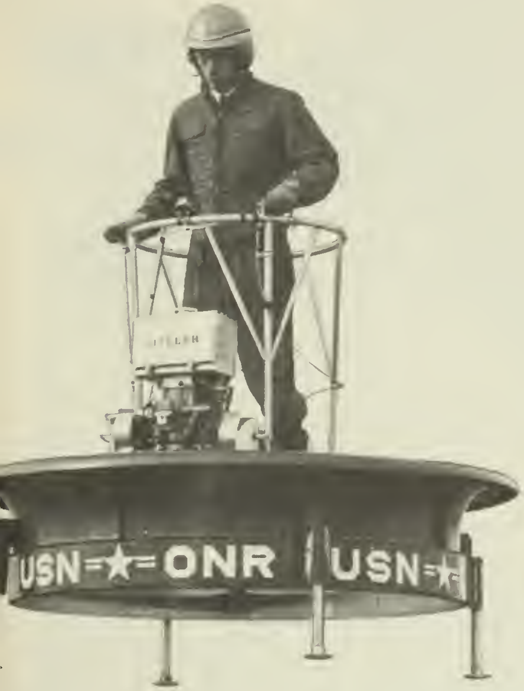
Meanwhile most aircraft will continue to obtain lift by application of aerodynamic principles involving air motion over a wing. For this reason, the next chapter will be devoted to showing how lift is achieved by a wing. Since the discussion there will be limited to conventional airfoils, it is not out of place now to mention and illustrate some other recent, and perhaps promising, variations. For example, the channel-wing, designed to achieve maximum lift with minimum forward motion, is still in developmental stages. It is said to permit landing speeds as low as 5 mph.



Courtesy of Custer Channel Wing Corporat

Experimental model of channel-wing aircraft. The half-barrel shaped wings are designed to permit extremely short take-off and landing runs.

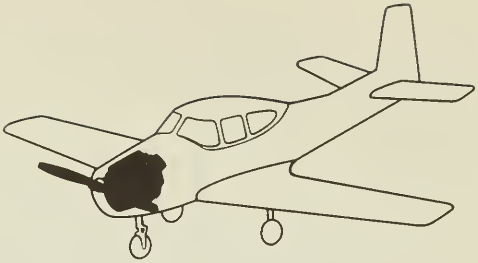
The coleopter, a joint French and German invention, employs a cylindrical wing and is designed to achieve vertical takeoff and landing. The ring-shaped [4] wing provides a ducted-fan effect similar to that of the "Flying Platform," and is quite capable of lifting the coleopter off the ground. However, stability problems have led to the addition of short conventional wings. The result is the Leduc 022.



U. S. Navy

Hiller "Flying Platform," the first aircraft to fly using the ducted-fan principle for lift and propulsion. The pilot guides the craft by shifting his weight in the direction he wants to go.

What success these and many other wing-variations may achieve is still a matter of conjecture. That they will have some kind of application to some future purpose can, however, be said with confidence.



PROPULSION

As we have seen, most modern aircraft rely upon a propulsion system as a source of power to provide both forward motion and lift. The first successful aircraft powerplant was the reciprocating gasoline engine, and it is still widely used. This type of engine is normally built to drive a propeller or propellers. The engine plus the propeller comprise a *propulsion system.*

More recent developments are various kinds of jet engines which propel aircraft through the atmosphere with a tremendous blast of hot gases, and the turboprop which combines propeller and jet blast.

The future possibilities in propulsion include a ramjet engine electrically heated by nuclear-decay batteries. Such an engine would require little or no fuel at its peak operating efficiency (high speed at high altitude). Another intriguing possibility for fuelless ramjet propulsion is based on the fact that, at very high altitudes (the ionosphere) the oxygen and nitrogen in the atmosphere are dissociated—they exist in atomic rather than molecular form. A ramjet might be designed to draw upon the vast energy which would be made available if these dissociated atoms were recombined by means of a chemical catalyst. A catalyst which will perform this operation was found in 1957. Since the catalyst itself would not be consumed in the process, no fuel whatsoever would be required for travel within the ionosphere.

Another source of thrust is the rocket.

Rocket propulsion is used on both manned and unmanned craft, but for various reasons it is at present better suited to missiles. The

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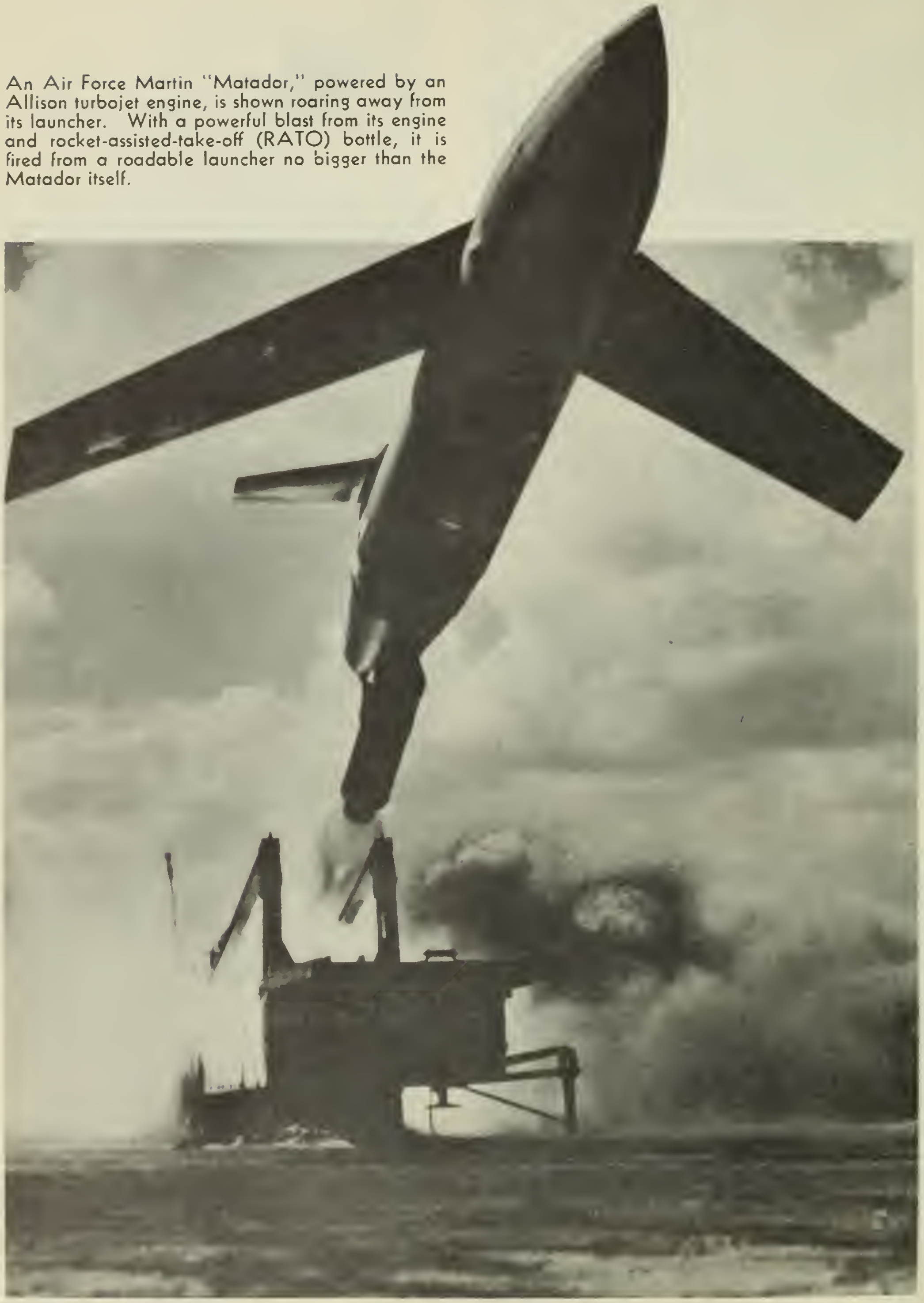
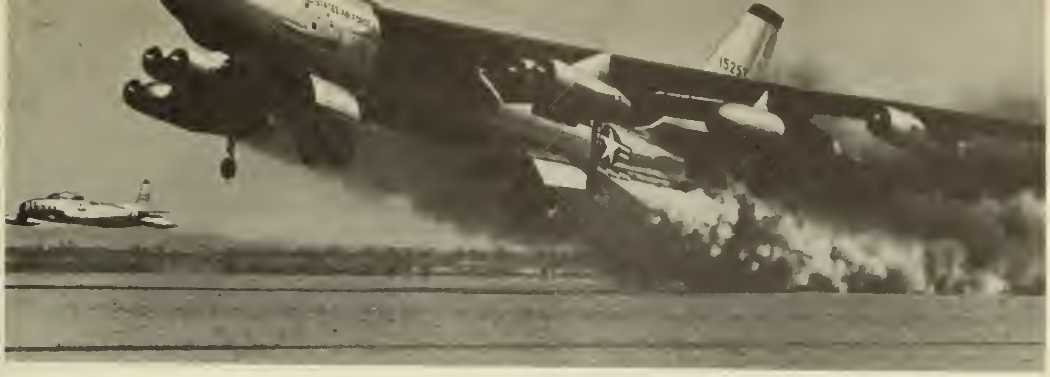
[1] Or collar-shaped. The French word for "collar" is *col.* The Greek word for "wing" is *pteron.* Hence, "coleo-pter." Consider the word "helicopter," from the Greek *helix* for "spiral" and *pteron* for "wing." Hence, "helicopter."

An Air Force Martin "Matador," powered by an Allison turbojet engine, is shown roaring away from its launcher. With a powerful blast from its engine and rocket-assisted-take-off (RATO) bottle, it is fired from a roadable launcher no bigger than the Matador itself.



U. S. Air Force Photo



U. S. Air Force Photo

An Air Force B-47 "Stratojet" making a rocket-assisted-take-off. Note its bicycle landing gear and the two outrigger wheels.

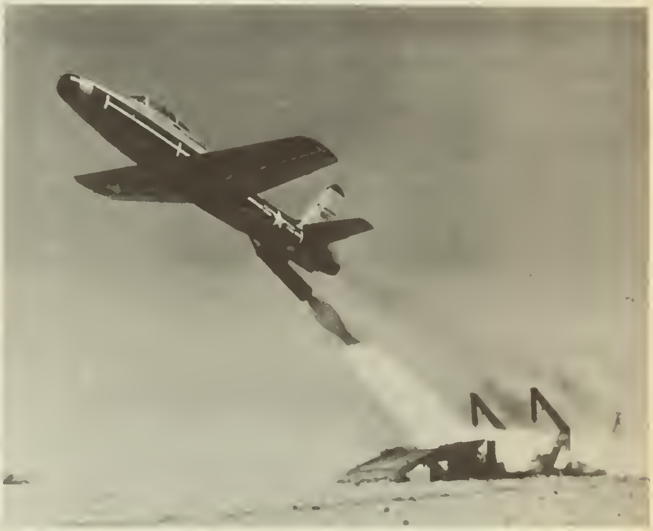
U. S. Air Force Photo

The Air Force B-36 heavy bomber uses a combination propulsion system. It is propelled by six pusher-type reciprocating engines and four jet engines.

rocket, however, has the tremendous advantage that it does not depend upon the existence of an atmosphere. It is therefore ideally suited to space travel.

There has been and probably will be much debate over the superiority of liquid or solid rocket fuels. At present solid fuels are safer to handle, but less powerful. The liquid fuels require far more complex machinery for pumping and combining but can produce greater thrust per pound of fuel.

New solid propellants made of nitropolymer compounds may bring both increased power and better reliability, and the so-called "exotic fuels" with a base of boron promise to deliver twice the power of the previous liquids. Plans were begun in 1957 for a Mach 3.0 bomber intended to fly at 75,000 feet, perhaps with a chemical-fuel ramjet.[5]



U. S. Air Force Photo

An F–84 "Thunderjet" is launched from the same truck-mounted platform used for the Matador, and using the same booster rocket. Despite the sudden acceleration, the pilot maintains full control at all times. The shock is less than that experienced in a catapult take-off. Such launchers may eliminate the need for take-off runways under certain combat conditions.

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[5] At 75,000 feet, Mach 3.0 would be nearly 2,000 mph.

At least one company is now building a rocket engine equipped with a throttle. This is a tremendous step forward, for all previous rockets burned at predetermined rates which were uncontrollable once the rocket was ignited. Rocket-powered transport planes are already being designed and some experts predict they may someday carry passengers from New York to San Francisco in little more than an hour. North American's X–15 piloted rocket plane is scheduled to fly as high as 100 miles at speeds up to 5,000 mph.

Nuclear reactors have great advantages as powerplants, and active research is now in progress under direction of the Air Research and Development Command to develop nuclear-powered aircraft. The energy available from a reactor is normally in the form of heat. Heat energy can be transformed to rotation of a propeller shaft or to some other form of propulsion. A turbojet engine powered exclusively by the heat from an experimental atomic reactor was tested in 1957. There also seems to be some possibility of using nuclear "batteries" instead of reactors. The answers are not yet known, but there is more reason to expect success than failure. Nuclear submarines are in operation. Development of the nuclear aircraft is only a matter of time.

Early in 1957, the Air Force announced that research contracts had been signed with Convair, Avro, Rocketdyne and other companies to explore *ionic drive,* a propulsion engine similar to a linear accelerator (rather like a straight-line cyclotron). The linear accelerator produces a blast of charged atomic particles, giving a very small but constant thrust. Ionic drive, which would be practical only in outer space, would theoretically drive a vehicle at velocities approaching that of light (over 670,000,000 mph). A space craft equipped with ionic drive would also have to have rockets or jets or some other propulsion system for use in atmospheres and to achieve "escape velocities." [6]

Combinations of two or more propulsion systems are not new. The B–36 uses both reciprocating gasoline engines and jet engines, the French SO–9050 Trident II interceptor has rockets in its tail and jet engines at each wing tip, and the British Saunders-Roe SR–53 will have a similar combination.

Many other radical proposals have been expounded from the "photon rocket" which uses light for propulsion, to "psychokinesis," a phenomenon related to mental telepathy. Most seem fantastic, and some are probably based on invalid assumptions, but we would do ourselves a great injustice if we ignored them merely because they seem absurd today. Tomorrow—who knows?

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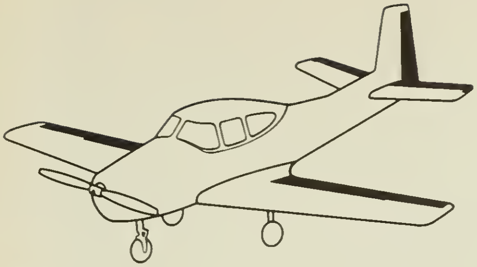
[6] *Escape velocity.* The velocity necessary to escape the gravitational pull of the earth or other satellite. For earth, it is 25,000 miles per hour.

Rocket-powered Bell X-2, designed to probe the "thermal barrier," shown resting on its ground service dolly.

U. S. Air Force Photo



CONTROL

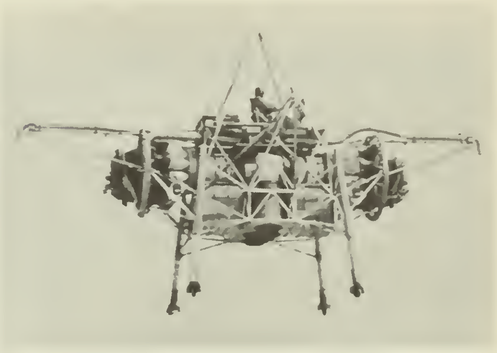
The fourth essential element of a flying nachine is a system to control its airspeed, lirection, attitude, altitude, and equilibrium. The exterior devices for aerodynamic control on a conventional aircraft are the ailerons, the elevators, the rudder, spoilers, and trim tabs.

In some aircraft certain control functions nay be combined in a single set of control surfaces, for example in the elevons of the 3–35 and B–49, the flaperon of the B–47, or n the V–tail of the Beech Bonanza. The spacial orientation (or "attitude") of an aircraft can also be controlled by other means. Experiments have shown the possibility of using air blasts directed in different direcions to control the attitude of certain VTOL (Vertical Takeoff and Landing) craft. The Vertijet controls its attitude during takeoff and landing by deflections of its jet blast. Certain missiles control direction and attitude by swivelling the rocket engine to various angles.

Attitude changes can also be brought about simply by altering the position of the center of gravity, as is well known to any pilot who has had to correct a C–45's elevator trim as the nose-tank fuel was used up, or who has felt the effects of unequal rate of flow from the tip-tanks of a jet. The Langley airdrome, which preceded the Wright "Flyer" but never flew successfully, was originally designed to achieve attitude changes by shifting the center of gravity of the aircraft. Perhaps some future craft will control its attitude by pumping a heavy liquid from tank to tank in the wings, tail, etc.

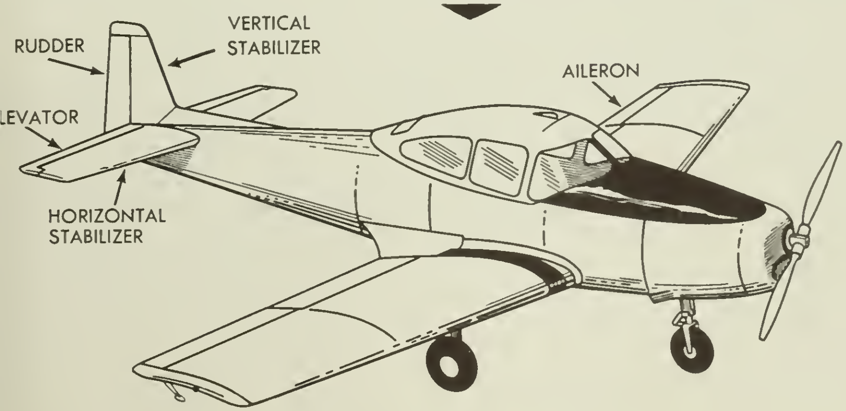
But like the wing, the conventional control surfaces are likely to be with us for some time, and we shall therefore treat them in detail later.

The British "Flying Bedstead" rises on deflected jet blasts. Stability is controlled by compressed air discharged through four outboard jet nozzles. ▶



Courtesy of British Information Services

Conventional control surfaces on the L-17 aircraft. ▼



NAVIGATIONAL DEVICES AND FLIGHT INSTRUMENTS

The fifth essential element is a system for controlling (or helping the pilot control) the path of flight. Whether manned or unmanned, an aircraft in flight is normally going to some particular place. Devices must be included, then, which will assure that it does not become lost.

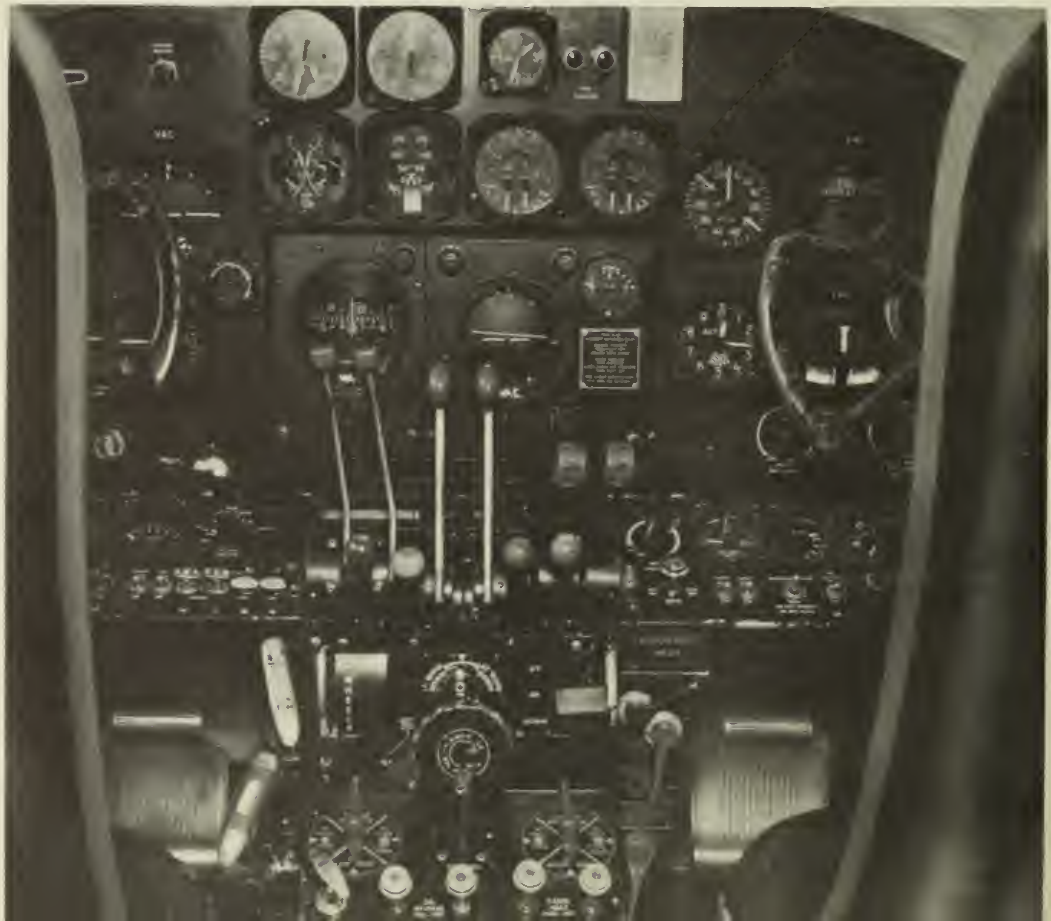
The basic navigational and flight instruments, found in even the simplest modern aircraft, are illustrated here: the altimeter, the airspeed indicator, the compass, and the clock. Others frequently found even in light planes are the rate-of-climb indicator, the thermometer, the gyrocompass, the "ball bank" indicator, and various kinds of radio navigation aids.

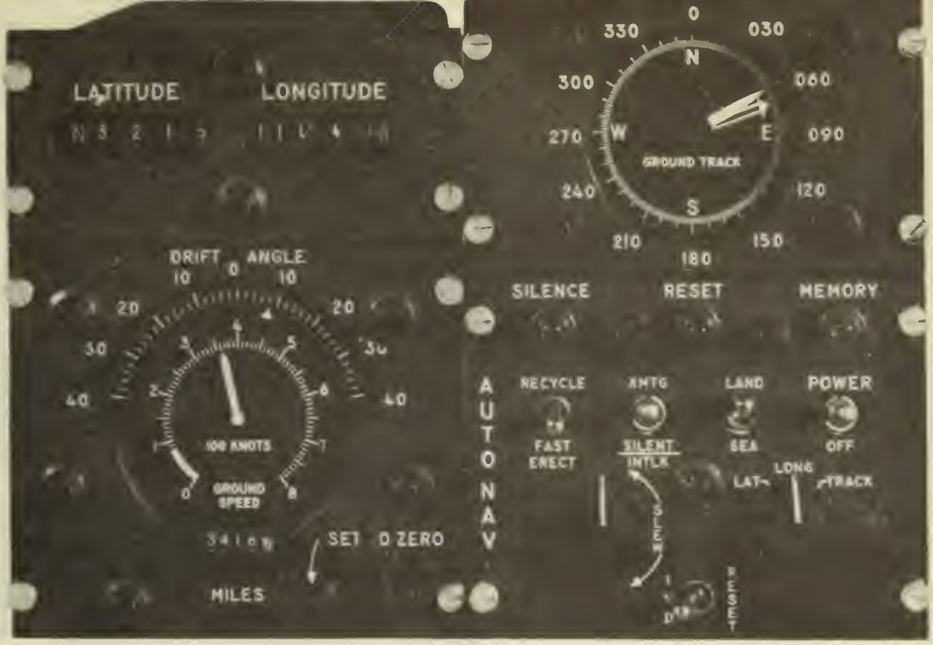
Of course, we may consider the window and the map as important navigational devices, too. But the window is of little use when flying over or through clouds. Many aircraft therefore carry electronic "windows" which provide a picture of the ground through the use of radar.

The automatic pilot can be considered a navigational aid, for it can control direction and altitude better than a pilot in many circumstances.

Instrument panel of a C-45 aircraft.

U. S. Air Force





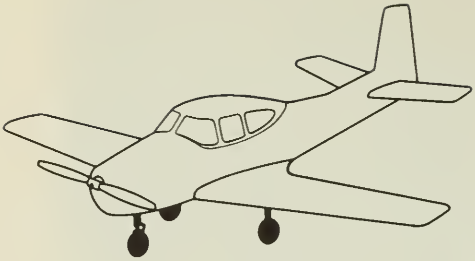
Courtesy of Ryan Aeronautical Corporation

his airborne, self-contained, electronic "automatic navigator," a Doppler system developed by by the U. S. Navy and Ryan Aeronautical Company, makes manual navigation computations almost unnecessary.

ese two instruments are the indicators of the very-
gh-frequency omnirange system (VOR). The sys-
m employs special transmitters located along prin-
pal air routes throughout the Nation and provides
extremely accurate and reliable navigation aid.

"Light multiplier" tube developed by Westinghouse for the Air Force's "Cat-Eye" system, a navigational aid that permits pilots to see in the dark with daylight clarity.

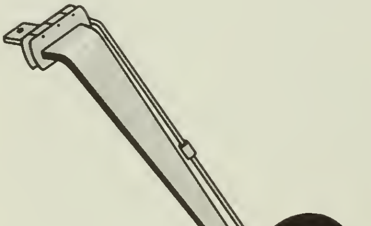
Courtesy of Westinghouse



GROUND HANDLING SYSTEMS

Unless the aircraft is designed to be destroyed on completion of its flight (i. e., missiles), it must have a sixth element—a landing device. The illustrations show some of the many kinds of devices designed to perform this function.

The landing gear presents great problems to the aircraft designer. In a bomber it accounts for 5 to 6 percent of the weight, and in a fighter it may account for a much as 8 percent. This weight is a dead burden in flight. Furthermore, the landing gear must be located near the aircraft's center of gravity (except for "bicycle" gear) and that is just where the designer wants to put the fuel and the load. The gear must be capable of withstanding tremendous shocks and yet be retractable to reduce drag. It must be strong enough to hold under great sideward stresses, and the mechanism for retracting and lowering must be near perfect in reliability.



Landing gear strut and wheel of an L–19 airplane.

From ATC Manual—Liaison Mechanics (US Air Force)

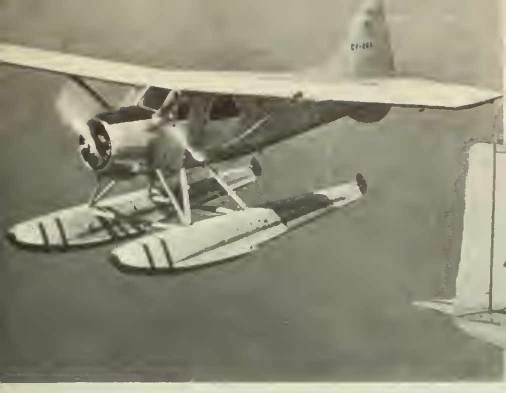
The flying boat aircraft eliminates gear, but the additional structures needed to strengthen the hull approach the same weight as landing gear. And a flying boat is a compromise between the most desirable aerodynamic shape and the best hydrodynamic shape and so cannot be the best of either.

U. S. Air Force Photo

The L–13, America's first all-metal liaison plane, uses a conventional landing gear.

One of the main landing gears on a B–36 bomber.

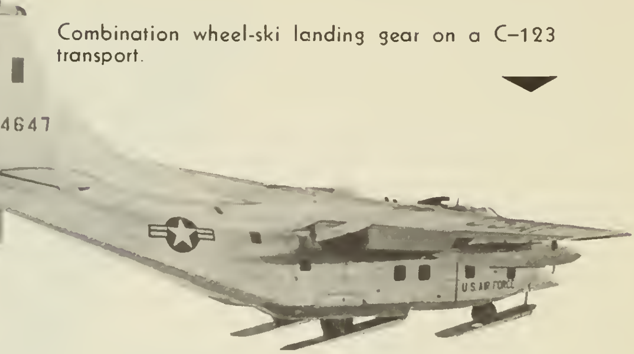
U. S. Air Force Photo



U. S. Air Force Photo

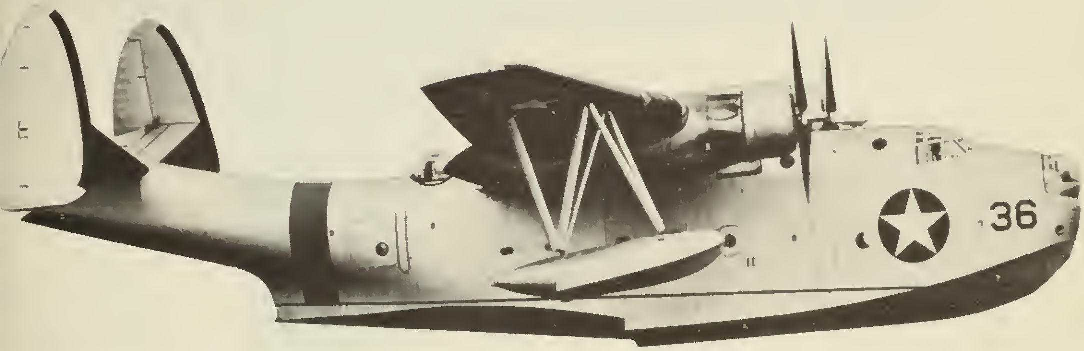
Pontoon-equipped De Haviland L–20 in flight. Named the "Beaver," the plane is used largely in the Arctic regions.

Combination wheel-ski landing gear on a C–123 transport.



U. S. Air Force Photo

The U. S. Navy PBM–3 "Mariner" flying boat.



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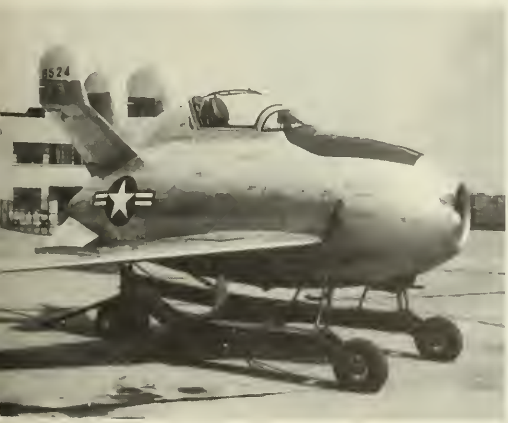
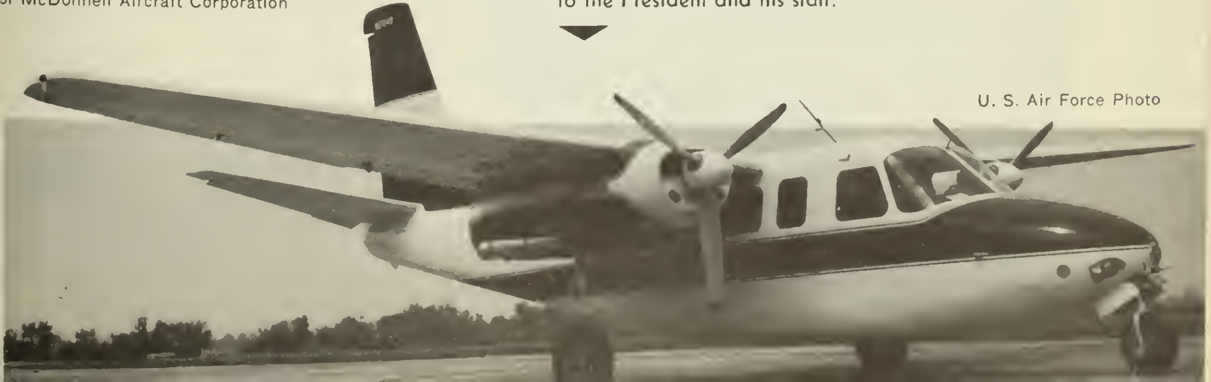


of McDonnell Aircraft Corporation

The XF–85 "Goblin," shown here on its ground service dolly, has stainless steel skids for landing. This parasite aircraft was developed to be carried in the bomb bay of a B–36 and be launched and picked up in flight.

Aircraft with tricycle landing gear. This is one of the Air Force's "Aero Commander" 560's assigned to the President and his staff.



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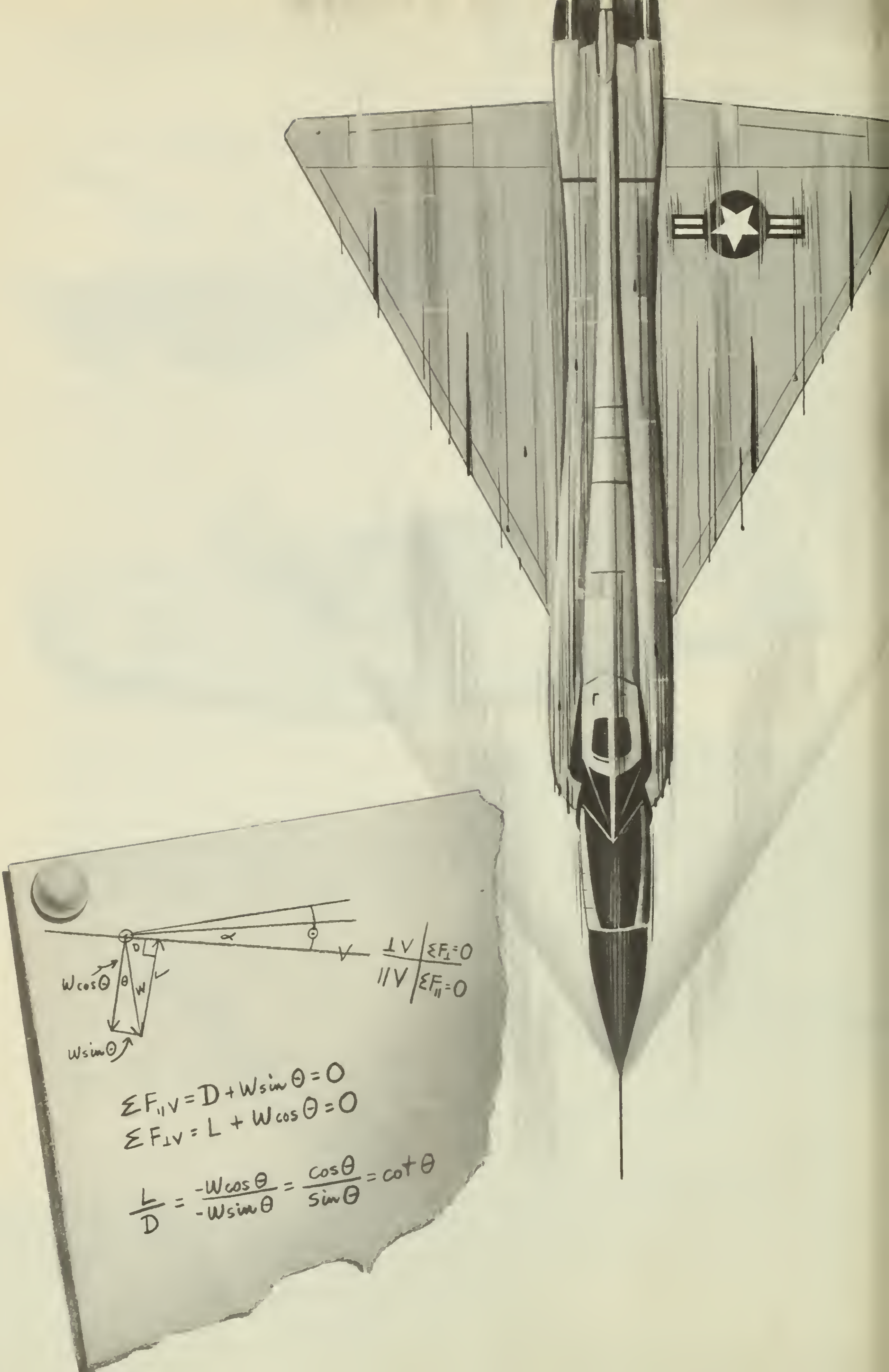

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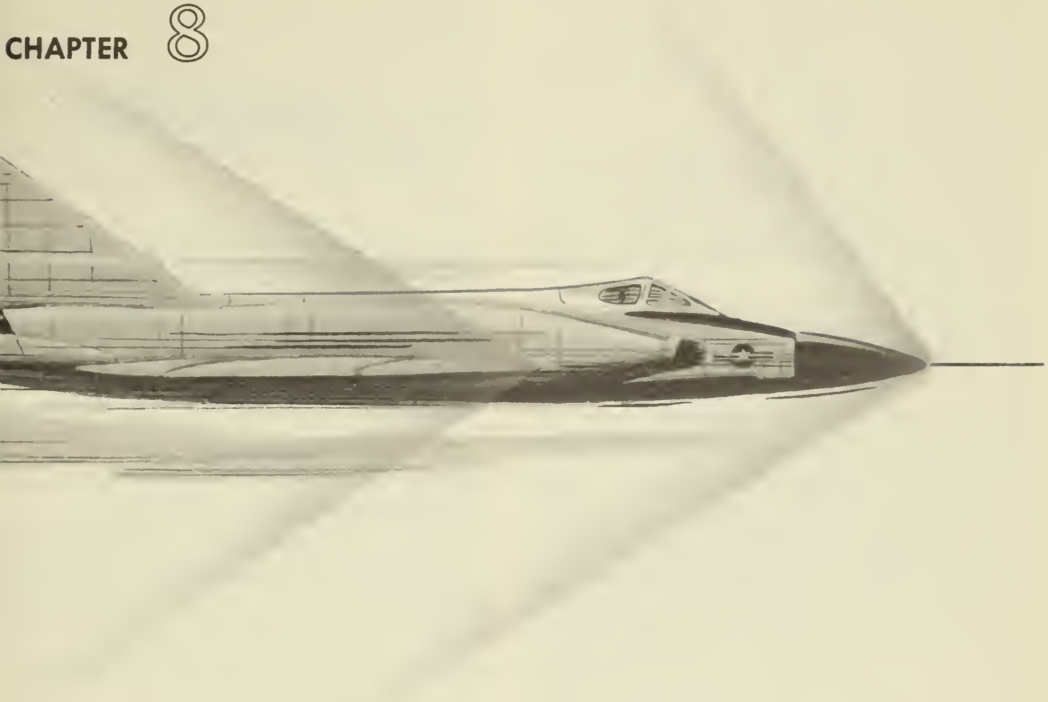
PART 2

CHAPTER 8



Aerodynamics and Lift

An airplane resting on the ground with its engine shut off has many forces acting upon it. All these forces are in equilibrium. As gravity pulls it down, an equal force presses upward on the tires from the ground. This is why runways and parking areas are paved. If a plane is parked in mud, gravity pulls it down into the mud until it settles upon something firm enough to provide an upward force equal to the gravitational pull.

Another force acting on the aircraft is atmospheric pressure. Air pressure is, of course, acting on everything in the atmosphere. When the plane is at rest, atmospheric pressure acts on all its parts and from all directions simultaneously and therefore cancels itself out.

The forces are all in equilibrium, and the plane remains at rest.

When the engine is started and the propeller begins to rotate, a new force begins to act on the plane, tending to pull it forward. This force is called *thrust*. When the thrust force is great enough, the plane begins to roll forward along the ground. (Pilots say it begins to "taxi.")

This force must first be great enough to overcome the inertia of the plane, plus the friction of the wheels. Once the plane begins to taxi at the desired speed, the thrust may be reduced. Only enough force is needed then to overcome the friction. If there were no friction, no thrust would be needed, for the plane's momentum alone would keep it rolling.

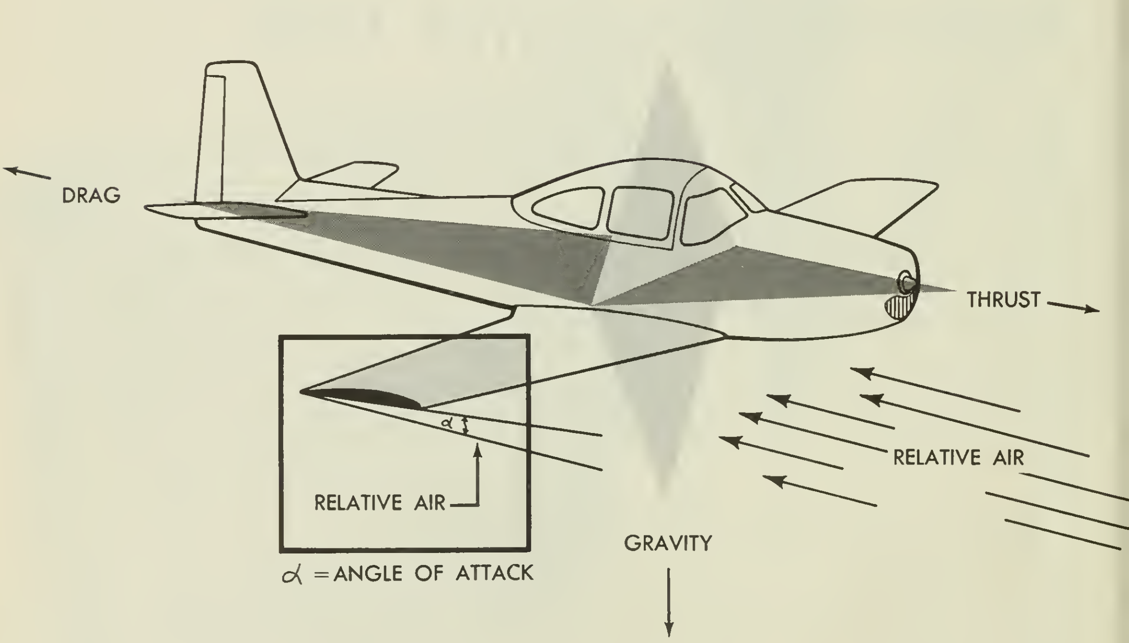
So, as it taxis along at constant speed, the forces are again in balance. Gravity is opposed by an equal force from the concrete surface, and friction is opposed by an equal thrust force.

As the plane starts down the runway to take off, the pilot applies nearly maximum power. As long as the thrust from the propulsion system is greater than both the wheel friction and the aerodynamic drag, the plane will accelerate and go faster and faster. The air flowing around the wing produces a lift effect which becomes greater the faster the airplane moves. When the lift force becomes greater than the gravitational pull on the plane, the plane is lifted off the ground. At this point, the pilot retracts the wheels (which cause tremendous drag in the wind) and the plane shoots ahead.

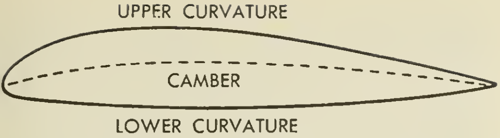
Now the power can be reduced. It will still be above normal, for some power is necessary to keep the upward forces greater than the gravitational force so the plane will climb.

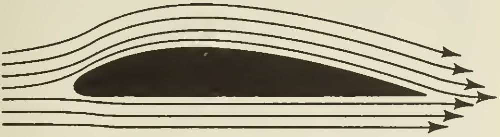
When the plane reaches and maintains the desired altitude, and is flying straight and level at a constant airspeed, the forces are again in equilibrium. The lift force pushing up on the plane is exactly equal to the force of gravity pulling down on the plane, and the thrust is equal and opposite to the drag. If the thrust is increased so that it becomes greater than the drag, the plane will accelerate. If the lift is increased and made greater than the pull of gravity, the plane will tend to climb.

As we shall see, the way these forces are related to each other is not at all simple. For example, if the pilot maintains constant



Forces acting on an aircraft.



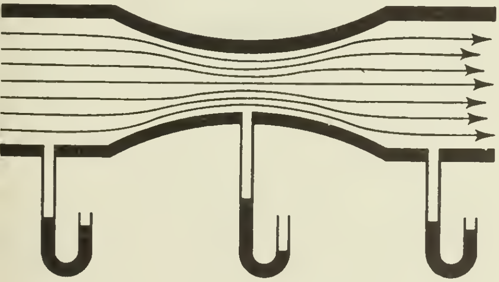


altitude but throttles back, reducing the thrust to a value less than the drag, the plane will slow down (decelerate). However, to maintain constant altitude as the plane slows down, he must steadily increase the angle of attack to keep the lift constant.

THE LIFT FORCE

An early theory of aerodynamic[1] lift is still often given as follows. The wing as it is commonly designed has a curvature on both sides, the greater curvature being on top.

The curvature of the wing is such that the air going over the top of the wing must go farther and therefore faster than the air passing over the relatively flat bottom side. The increased velocity of the air while moving along the curved surface of the wing makes applicable the physical law discovered and defined by Bernoulli. Bernoulli's law states that when air volocity is increased this way, it exerts less pressure against the surface over which it is passing. There is, then, a *lowered* pressure on the top surface of the wing.



Venturi tube illustrating Bernoulli's Law.

The normal atmospheric pressure at sea level is almost 15 pounds per square inch. This pressure is pressing on all parts of the wing when the wing is motionless in the air. However, when the wing is moving through the air the pressure on the top surface is *less than normal.* On the other hand, while the pressure on the bottom surface may decrease, it will not decrease as much. The result of this difference of air pressures is that the wing is pushed up from below into the low-pressure area.

The pressure difference between the two surfaces of the wing is not very great, but with the normal atmospheric pressure at about 2,000 pounds per square foot,[2] only a small percentage of pressure difference will result in a considerable total force being exerted to lift the wing. For example, a mere two percent difference in pressures would result in an upward force of 40 pounds per square foot. A rectangular wing 30 feet long and 5 feet wide would then produce 6,000 pounds of lift force.

The preceding explanation is a considerable oversimplification of the way lift forces are produced on a moving airfoil. The resultant effect is accurate, but the explanation is incomplete and rather misleading. An explanation based solely on the Bernoulli theorem requires an almost complete revision of our thinking when we come to consider the process in greater detail.

The Generation of Lift

Unfortunately, a complete and fully accurate explanation of aerodynamic lift would be too complex for a brief course such as this, but certain aspects of current theory can and will be discussed here. The following paragraphs will certainly raise many questions which simply cannot be answered in an elementary course. It is hoped, however, that they will provide some insight into the highly technical science of aeronautical engineering. If you wish to delve deeper into the subject, your instructor can recommend several authoritative and easy-to-read books.

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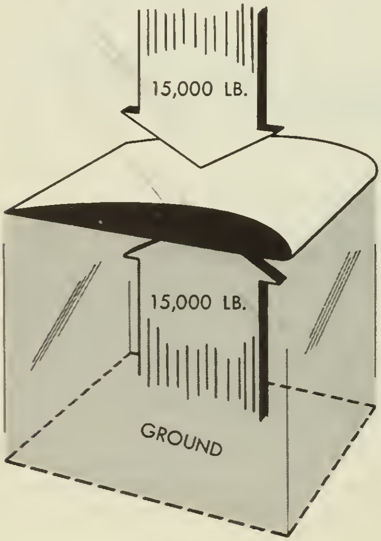
[1] The word "aerodynamic" comes from the Greek *aeros* for "air" and *dynamis* for "power." Aerodynamics, then, is the study of the behavior of air and other gases when forces are applied to them.

[2] Actually, about 14.7 pounds per square inch × 144 square inches=2,116.8 pounds per square foot.

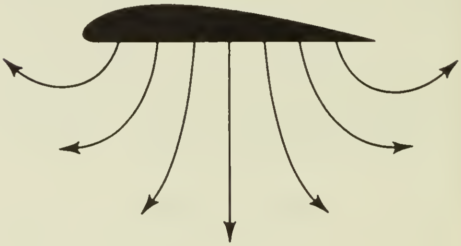
Imagine for a moment a plane weighing 15,000 pounds and having a wing that looks something like this.

We shall assume for the moment that this wing is essentially flat on the bottom. In flight, this wing will be pushing down on the air below it with a force of 15,000 pounds.

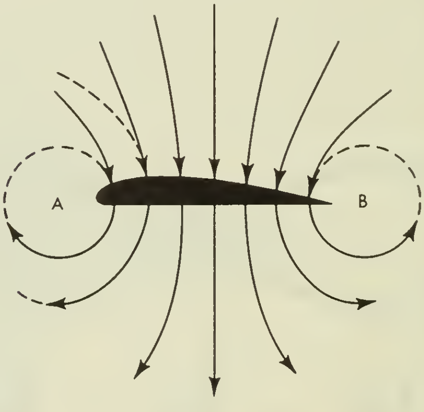
If this air were contained in a glass box exactly the size of the wing, and if the air were incompressible, the wing would sit on top of the column of air and would not fall. The air column would provide an exactly equal and opposite reactive force to hold the wing in position.



But there is no such box. If the wing is suddenly pushed down against the air with a force of 15,000 pounds, the air will react against it, but not with a 15,000-pound force. The air will "give way" and pressure waves will be sent down through it at the speed of sound. The air will be pushed out of the imaginary box. (Note that we have now switched to a two-dimensional diagram. The process is, of course, three-dimensional.)

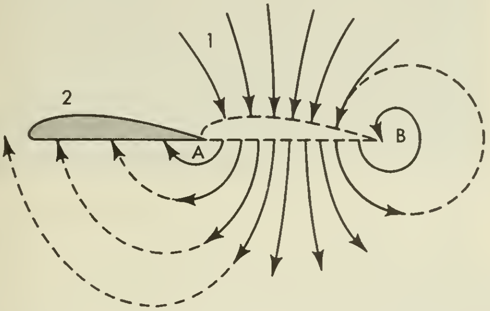


Atmospheric pressure is, of course, also acting on the top of the wing, and when the wing is pushed downward, the air above it follows it down. This creates a lowered pressure on top which assists the "circulation" from bottom to top.



The particles of air do not flow from bottom to top; it is only the pressure pulse that moves. We can see the beginnings of "whirlpools" (or *vortices*) as represented by the dotted lines in the preceding diagram. But remember that it is actually air from above which comes in to complete each vortex. The air below does not actually move up and around to the top surface.

So far, we have considered the wing standing still. Suppose we now move the wing along a bit and prepare to give it another downward push.



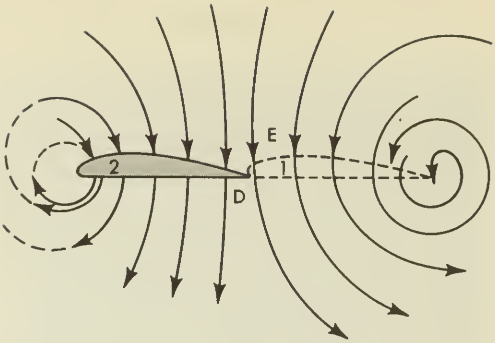
This second downward push will be met not only by the natural reaction of the air below the wing as before, but also by upward forces associated with the first push. Notice point A.

Another thing to notice here is that the little vortex that started to form at the leading edge of the wing never gets a chance to form. The leading edge keeps moving forward, so that the updraft air at the leading edge passes back over the top of the wing.

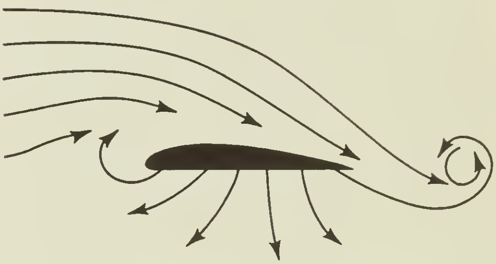
Since the wing has now moved, the pressure circulation which would have come down on top of the trailing edge at point B does not do so, so the simple equalization of pressure that we might have expected here does not occur. Instead, as we shall see later, a whirlwind or *vortex* is started here.

The second downward push tends to set up a system of pressure circulation just like those of the first push. But a second, identical, pattern is now impossible, because there is interference with what remains of the pressure system caused by the first push.

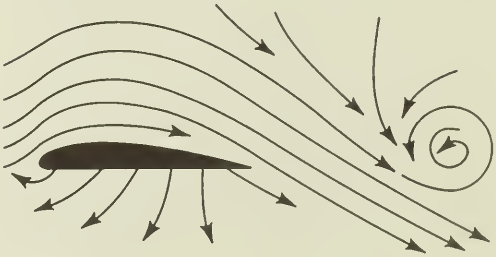
So the pressures below the wing now move more directly downward (more like the glass-box situation) and more nearly forward at the leading edge. Notice, too, the reinforcement of the trailing-edge vortex by the situation at E. The air which was descending to follow the wing down actually becomes part of the downwash.



If we translate this into a picture at some considerable speed, we will get a picture something like this.



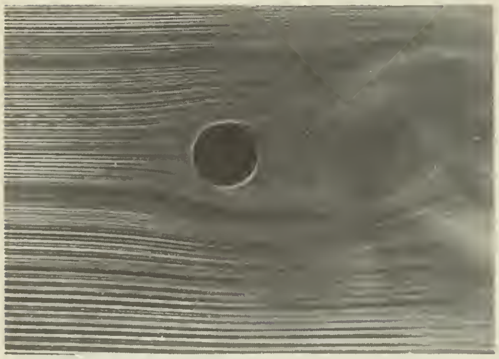
And if we add the complication of the airfoil moving forward through the air mass at say 200 mph, the picture begins to look something like this.



Now it is a law of physics that if a rotation is created in any body, there must be an equal and opposite reaction force against the body which causes it.

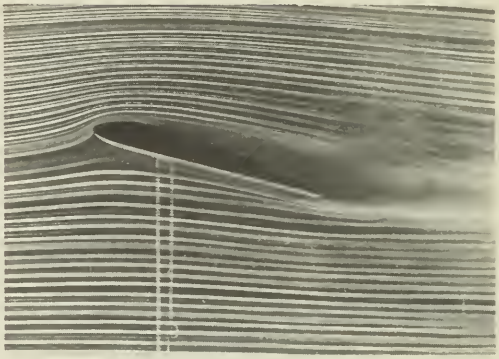
Smoke stream photographs showing the character of airflow around various airfoils.

U. S. Air Force Photo



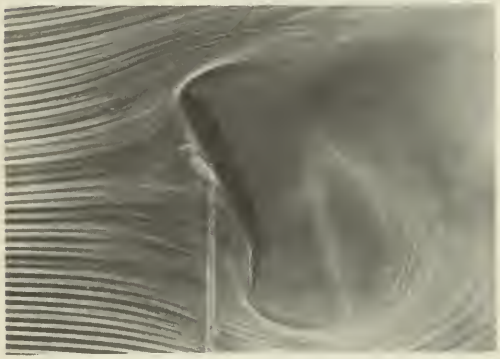
Airflow around a cylinder. The picture shows the formation of eddies and a low-pressure area behind the cylinder. Note how the air curls in first from one side and then the other.

U. S. Air Force Photo



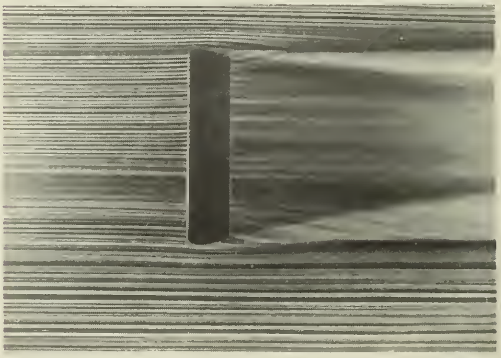
Airflow around airfoil at high angle of attack. Partial separation is taking place, but lift is decreased only slightly. A ruler placed across the picture will show that even the air above the wing leaves the picture lower than it comes in.

U. S. Air Force Photo



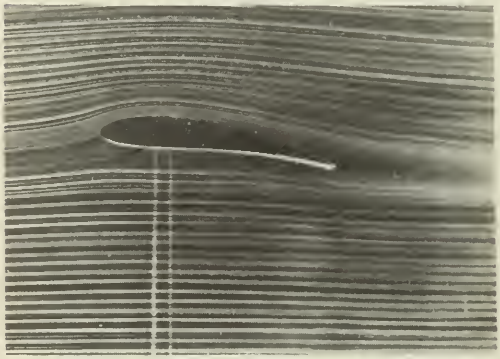
Airflow around an airfoil at extreme angle of attack. Like the preceding photograph this one also shows the presence of a low pressure area and eddy currents behind the obstruction.

U. S. Air Force Photo



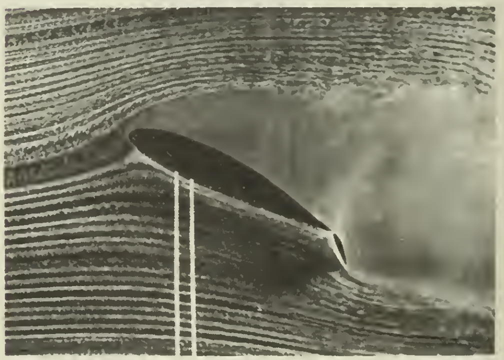
Airflow around model wing viewed from above. Note the vortex pattern at the wing tips as the air curls up from below the wing.

U. S. Air Force Photo



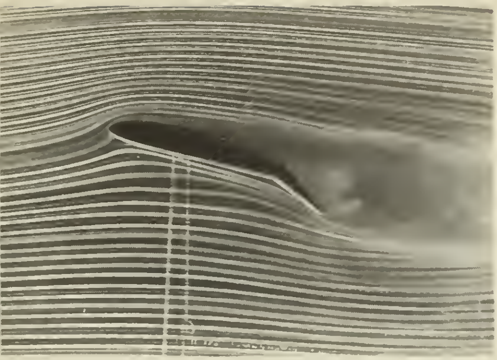
Normal airflow around an airfoil. Note that the air both above and below rises slightly as it approaches the airfoil and is deflected downward as it leaves it.

U. S. Air Force Photo



Airfoil with flap in stall condition. The air has completely broken away from the upper surface of the airfoil resulting in complete separation. Note effect of flap.

U. S. Air Force Photo



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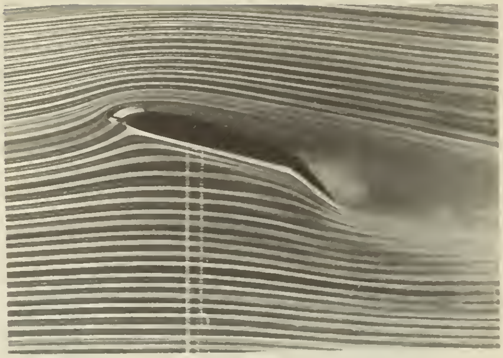
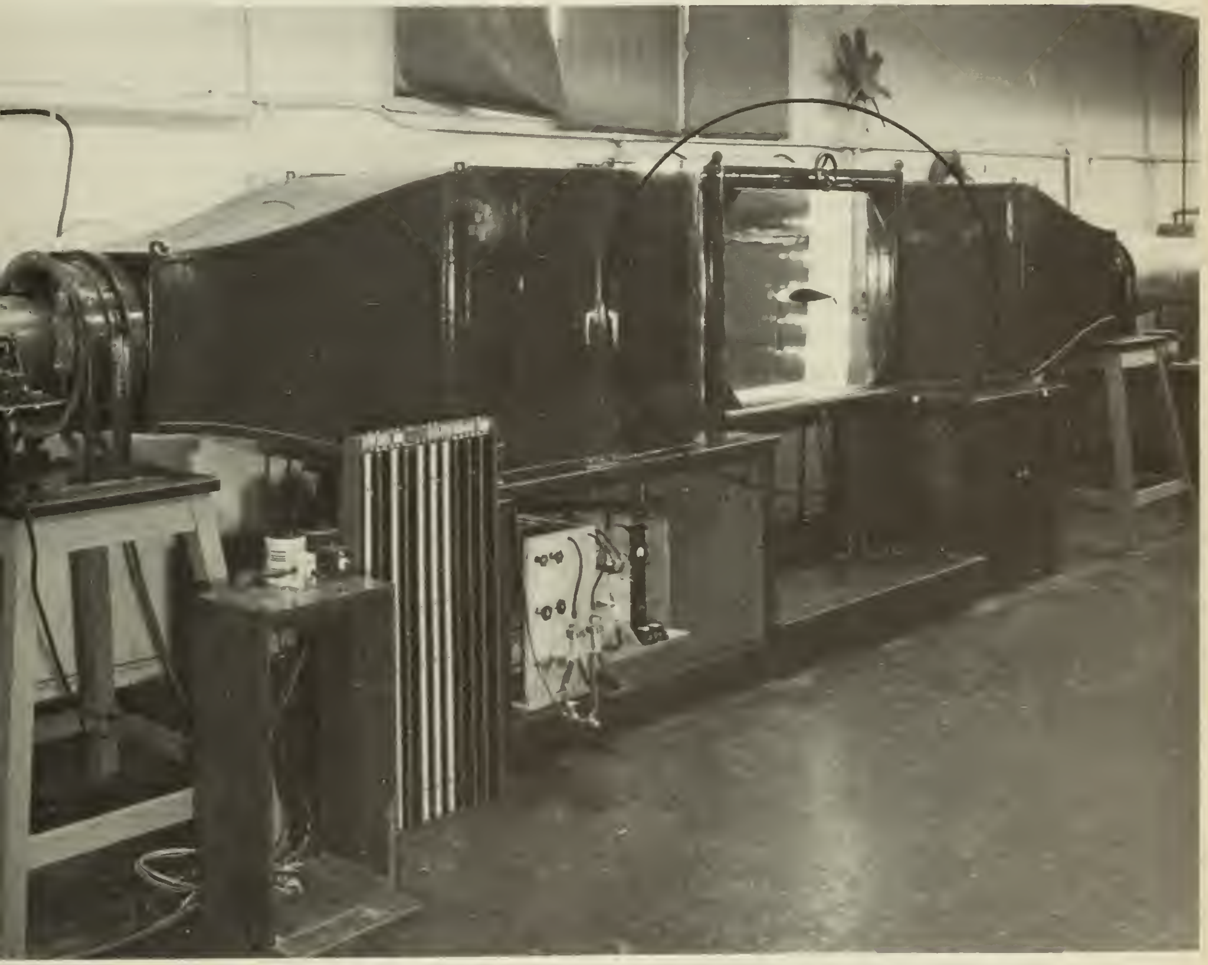


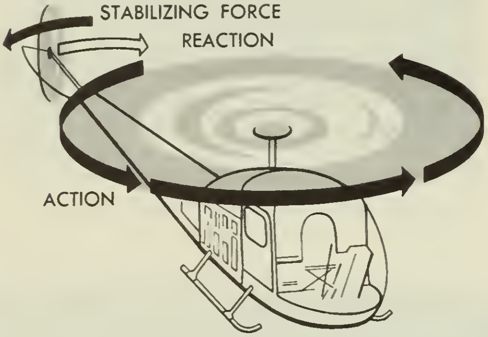
Airflow around airfoils with flaps at high angle of attack. Note the smoother flow of air in the photograph to the right in which the slot at the leading edge of the airfoil is extended.



U. S. Air Force Photo

The smoke pictures reproduced here were made with this equipment in the Aeronautical Engineering Department of the Air Force Institute of Technology, Wright-Patterson Air Force Base, Ohio.

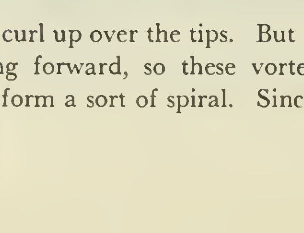
We see this principle at work in the helicopter. As the rotor is made to revolve, the fuselage has a strong tendency to rotate in the opposite direction. This tendency is so strong that a small propeller must be mounted on the helicopter's tail to counteract it.

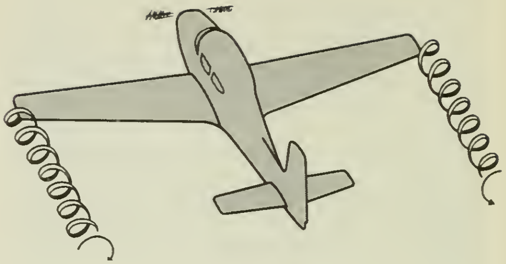


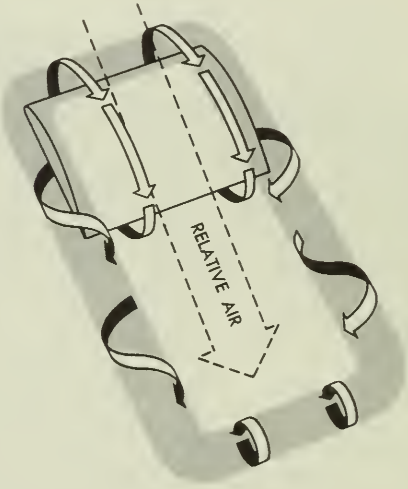
Similarly, if a movement of the air behind the weighted wing creates a trailing-edge vortex (a rotating body of air), then an equal and opposite rotational force is applied to the rest of the air. This reaction force is what, in effect, creates the circulation around the wing.

At the wing's leading edge there is an upwash of air rising to pass over the top of the wing. If this upwash were equal to the downwash behind the wing, no lift force would be generated. But the downwash behind the wing is much greater than the upwash in front. The reason for this lies in the effect of the wingtip vortex.

Just as the air tended to curl up over the leading and trailing edges when the wing was given its first downward shove, it also tends to curl up over the tips. But the wing is moving forward, so these vortex forces actually form a sort of spiral. Since the air in this vortex system is traveling downward on the side toward the wing, it contributes to the amount and the velocity of the downwash behind the wing. The diagram of the complete vortex system shows why.





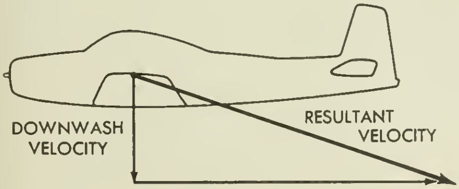


The preceding discussion involved a series of downward pushes on the wing. We know this is not the fact in flight, for the process is continuous, and also there is no loss of altitude as implied by the words "downward push." In truth, the front of the wing is tilted up at a slight angle (the "angle of attack") so that the wing "climbs" through the air. The air, however, is descending at the same rate. It is as though the wing "climbs" a descending flow of air, thus remaining at a fixed altitude, like a man climbing a descending escalator.

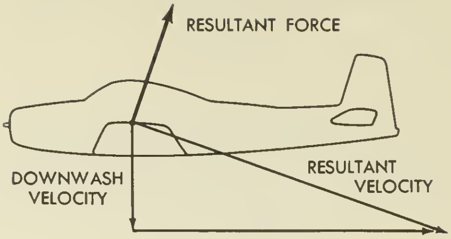
To “climb” like this takes work, and since the only source of energy is the propulsion system, the continuous force necessary for this “climb” is drawn from the thrust force. It therefore appears as a force directly opposite to and therefore subtracting from the thrust force and is called the “induced drag.” A portion of the thrust force from the propulsion system—a portion exactly equal to the induced drag—is therefore the ultimate source of the lift force, and is the price we pay for the phenomenon of aerodynamic lift. In the last analysis, it is the propulsion system (which is, after all, the only *work*-producing system in the aircraft) hat supplies the energy necessary to keep an aircraft aloft.

To understand this better, we shall need o examine it from a slightly different point of view. This, in turn, requires us to learn a few special terms. The first of these is *elative air,* which is the velocity of the air rushing past the wing or, looked at another way, the velocity of the wing through the air. When the plane is flying straight and evel, this velocity is in a horizontal direcion.

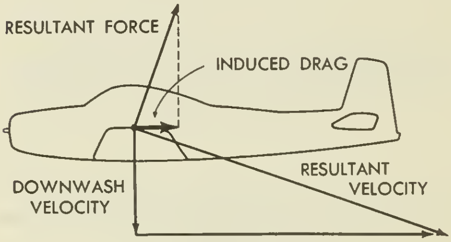
As we have seen, the moving wing creates a vortex system which shoves air downward. The combination of the relative air's original horizontal velocity with this downward shove (the “downwash”) is the *resultant velocity.*



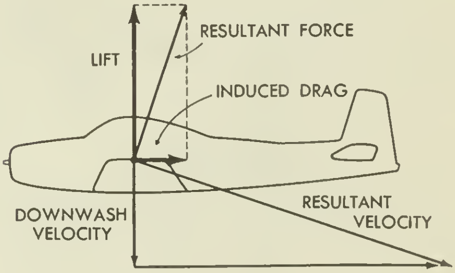
The actual upward force generated by the aerodynamic effect of a wing traveling through the atmosphere is called the *resultant force.* The resultant force is always perpendicular to the resultant velocity, and not perpendicular to the relative air.



Since it is perpendicular to the resultant velocity, which slants downward, the resultant force slants backward somewhat from the vertical. The induced drag can therefore be represented as the amount that the resultant force slants back and holds the plane back.



The term *lift* refers to the upward force perpendicular to the relative air. Lift is sometimes defined as a force opposing gravity, and sometimes in other ways, but aeronautical engineers prefer to define lift as a force perpendicular to the relative air, regardless of the plane's attitude.



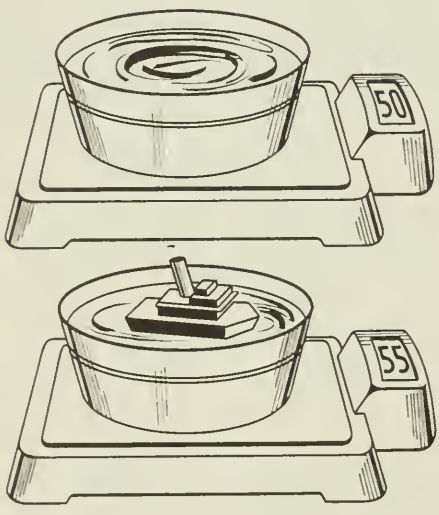
It can be proved that if we divide the lift by the amount of induced drag, we will obtain the same number as when we divide the relative air velocity by the downwash velocity.[3] From this equation, we can see that (other things being equal) the lift created by a wing will increase directly with the plane's velocity. Or if the lift be maintained at a given value, and if the velocity of the plane is increased, the induced drag must decrease. And this is actually the case: the induced drag decreases as the speed increases.

$$\frac{\text{Lift}}{\text{Induced Drag}}=\frac{\text{Relative Air Velocity}}{\text{Downwash Velocity}}$$

The wing produces lift by driving air downward. The more rapidly and efficiently it does this, the more lift it will produce. A wing is therefore the same, in this respect at least, as a helicopter rotor, a ducted fan, or other lift-creating devices.

But it is not the air that ultimately supports the airplane.

Consider a tub of water weighing 50 pounds. If you float a 5-pound toy boat in it, the combination must weigh 55 pounds. The boat does not cease to have weight merely because it is floating; its weight, too, must be supported by the scale.



Ultimately it is the earth that provides the reaction upward against the air directly beneath the aircraft. The air merely transmits the weight of the aircraft down to the ground. But since the air pressures decrease with the square of the height of the aircraft, they are extremely small by the time they reach any particular point on the ground (unless the plane is only a few feet up). This is mainly because the pressures spread out as they travel and are therefore very widely distributed on the surface. Nevertheless, a barometer of sufficient sensitivity would detect a slight increase in pressure as a plane approached and flew over it, just as it would detect a car passing on a highway, if it were not too far from the edge of the road.

FORMS OF DRAG

Drag is the force that resists the forward motion of an aircraft. We have already examined induced drag, which is one form of *drag-due-to-lift*. The kind of drag-due-to-lift which occurs in supersonic flight is rather different in nature. It is sometimes called induced drag, but that is incorrect. Induced drag is a subsonic phenomenon.

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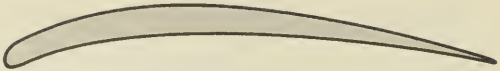
[3] This is true so long as the downwash velocity is less than 10 percent of the relative air velocity. In certain vertical takeoff aircraft, this may not be the case.

The amount of induced drag created by a wing in flight is, in part, a matter of how the wing is designed. Since every pound of drag force must be overcome by a pound of thrust from the propulsion system, aeronautical engineers take great pains to design aircraft for minimum drag.

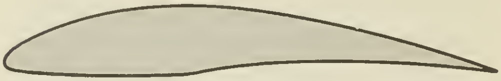
One of the design features of a wing is its *aspect ratio*. In a rectangular wing, this is the ratio between the wing-span and the wing width.[4] If the span is 30 feet and the width is 5 feet, the aspect ratio is 30/5 or 6.0.

Other factors remaining constant, the higher the aspect ratio, the lower the induced drag. Thus, for the same amount of lift at the same speed, a long narrow wing causes less induced drag than a short, wide one.

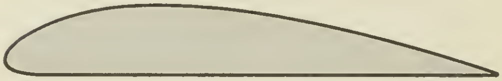
An aircraft designer planning a cargo plane gives it a high aspect ratio to reduce the induced drag and therefore the power requirements. High aspect ratio tends to keep the cruising speed low, but the low



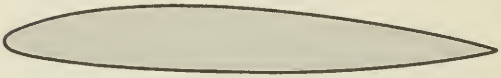
EARLY AIRFOIL



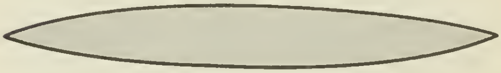
LATER AIRFOIL



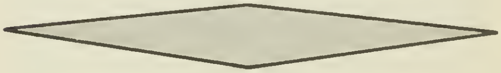
CLARK "Y" AIRFOIL



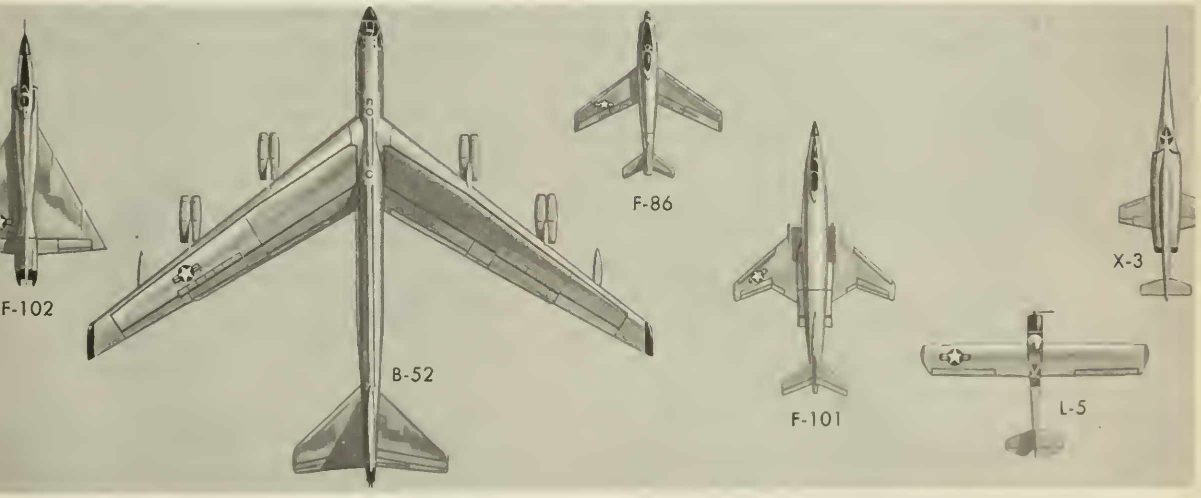
SUB-SONIC AIRFOIL



SUPERSONIC AIRFOIL



SUPERSONIC AIRFOIL



The planform or outline shape of the wing is determined by several factors in the design specifications of the airplane, such as the size and weight of the airplane, its speed, its range, its operational altitude, and its function.

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[4] Technically, it is the ratio of the square of the span to the area. In engineering terms, the aspect ratio is the span squared, divided by the span times the "mean aerodynamic chord." The "mean aerodynamic chord" can be very roughly defined as the average width of the wing.

drag permits long range with practical fuel loads.

Very fast planes such as fighters are usually designed with shorter wings. Long wings slow down the rate at which an aircraft can roll, and quick manuverability is a necessity in a fighter. Also, shorter wings can be built stronger and stiffer so that bending and fluttering are reduced. The low aspect ratio may result in shorter range at subsonic speeds, but at supersonic speeds, induced drag is relatively low and low aspect ratios can be used conveniently.

All kinds of drag other than induced drag are classed as *parasite drag*. One kind of parasite drag results from low-pressure areas associated with the many turbulent eddies of air that form in back of any part of the plane that sticks out into the airstream. The "pressure drag" caused by the landing gear, for instance, is so great that nearly all fast aircraft have a means of retracting the gear up into the wings, fuselage, or engine nacelles. Eddies can be caused by anything that sticks out; round rivet heads, antenna masts, pitot tubes, lights, guns, external rocket launchers or bomb racks, dive brakes, and so on. Each of these eddies is a little whirlpool or vortex of air, and each is accompanied by a low-pressure area behind the protuberance which caused it. This form of drag can be reduced by streamlining the protuberance so as to reduce the wake it causes, or by retracting it, or by eliminating it.

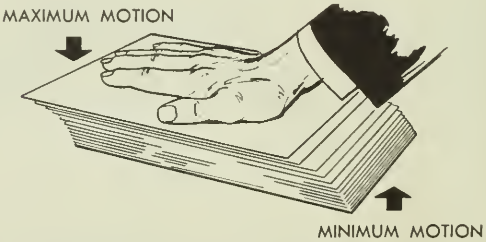
The Boundary Layer and Skin-Friction Drag

Another form of parasite drag is called *skin friction drag*. As an aircraft moves through the air, the air that is actually in contact with the plane tends to stick to its skin and move along with it. This is because of molecular attraction (friction) between the air and the skin. The layer of air next to the skin is called the *boundary layer*. It tends to drag the air near it along, too, but to a lesser extent. The farther away from the skin, the less the air is affected by the skin friction. There is no simple and exact definition of how thick a boundary layer may be, but we can think of it as a thin layer of air, right next to the skin, which is most affected by friction with the skin.

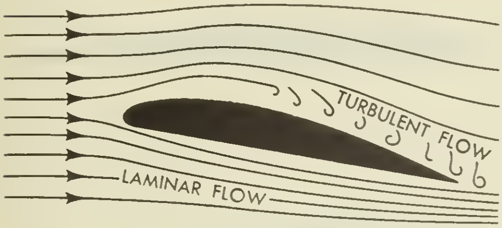
The particles of air nearest the skin tend to be dragged along at the same speed as the aircraft. These particles were standing still before the plane got to them and the plane "picks them up" and suddenly gives them a velocity equivalent to that of the plane. Then, immediately, these particles are "knocked off" the skin by impact with the next particles the aircraft runs into. This process goes on continuously and obviously requires an expenditure of energy; to accelerate any mass from zero velocity to say 400 mph, takes work. This work is of no use to the aircraft. Accelerating air forward in this manner does nothing at all to help the aircraft fly. So this is wasted work—drag.

Laminar Flow

Smooth, even flow around the wing, fuselage, or tail surfaces is called *laminar flow*. It is easiest to illustrate *under* a wing. Imagine a deck of cards on a table. This represents the theoretical layers (laminations) of air. Now if you press your hand (representing the wing) on the deck and slide it forward, the top card will stick to your skin and slide with it, the next will slide almost as much, the next a little less, and so on.



Laminar flow is maintained as long as the pressures decrease from front to back along the surface of the wing. That way, the airstream is always flowing into an area of lower pressure, which is a natural thing for air to do. Under certain conditions, however, areas of higher pressure will develop behind areas of lower pressure. Whenever this happens, the air in the boundary layer may become turbulent, and the laminar flow is destroyed. The skin-friction drag of turbulent flow is much greater than that of laminar flow.

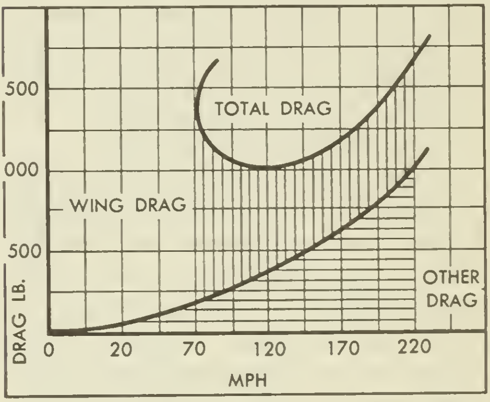


Boundary layer friction can never be eliminated, but it can be reduced by very careful shaping of the wing, by making the skin very smooth—even polishing it—or by pumping the boundary-layer air away. This is done by making special holes in the surface of the wings, pumping the air into the plane, and expelling it behind. This maintains the necessary low pressures along the wing. At high speeds—even below the speed of sound—nearly all the drag comes from skin friction. It may be so great that over half the horsepower of the plane may be spent to overcome it.[5]

THRUST AND DRAG

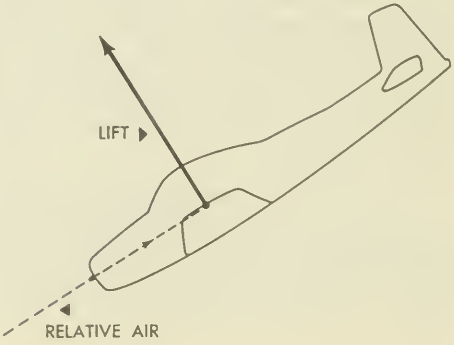
As previously noted, thrust is a forward-acting force and drag is a backward-acting force. During periods of constant speed, when the airplane is neither accelerating or decelerating, these two forces are equal in magnitude. If the output of the propulsion system is increased so that the thrust exceeds the drag, a level-flying airplane will increase in airspeed. However, the increase in airspeed will also cause an increase in drag and at some new and higher airspeed the thrust and drag forces will again be equal and speed will again become constant.

If the engine output is gradually increased, the propulsion system will eventually reach its maximum thrust, and the airspeed and drag will continue to increase until the drag force again equals the thrust force. A constant airspeed will then prevail. This will be the top speed for the airplane. If thrust becomes less than drag, the airplane will decelerate—will go slower and slower—until thrust and drag become equal again. With increase of airspeed, parasite drag increases very rapidly, for it is not a simple one-to-one increase.



CHANGES IN LIFT

If we increase the speed of an aircraft, we increase the velocity of the air flowing around its wing. As we saw a few pages back, this will result in increased lift. This will be true even in a dive. (Remember that the "lift" always works at right angles to the relative air.)



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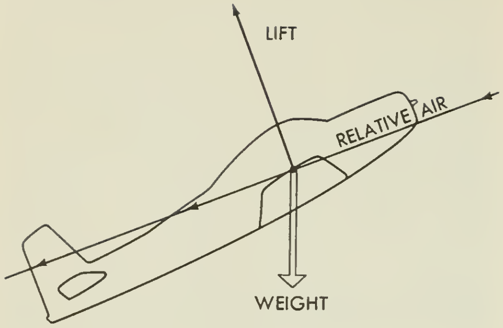
[5] Recall that the induced drag *decreases* as the speed is increased.



The density of the air also has an effect on lift. At high altitudes, where the air is thin, greater speed is required to create the lift than is required at sea level. Thus, an aircraft taking off from Denver, the "Mile-High City," needs a longer runway to get more speed before it begins to fly.

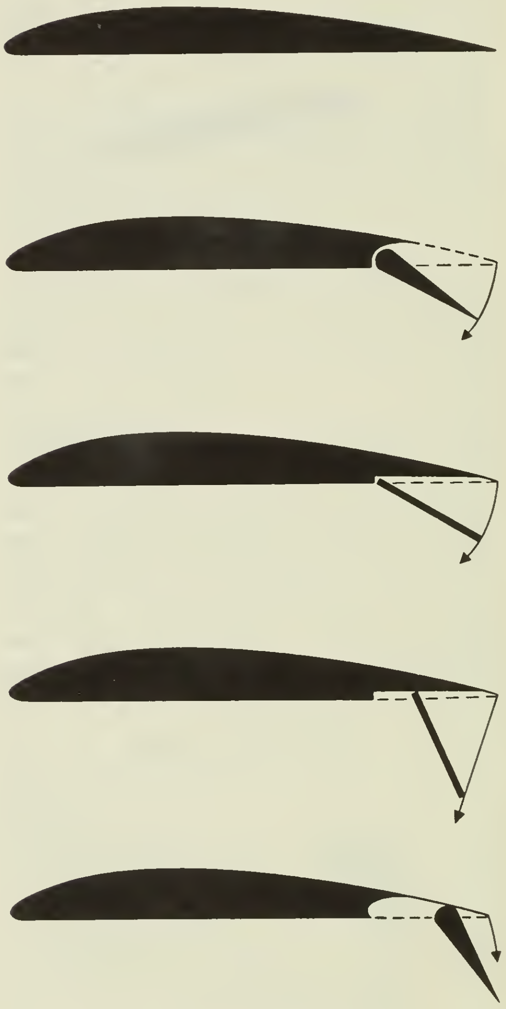
Another way to change the lift of a wing is to give it more or less camber. A plane designed for slow flight and heavy cargo has a thick wing with a large curvature on top for minimum drag and greater lift at a given angle of attack. Highspeed planes require thinner wings with less camber to avoid the compressibility effects that occur at high speeds.

It is also possible to design a wing with adjustable camber. The principal method of doing this is to use a wing with a hinged trailing edge. Wings have also been designed with hinged leading edges, and some with both. Such devices are shown in the illustration.

With the movement of hinged trailing or leading edges the pilot is able to control, within limits, the amount of lift a particular airfoil may produce. This principle of changing camber is the basis of the conventional control surfaces and the devices known as "flaps."

Another way to increase the lift of a wing is to nose the plane up. This increases the angle of attack—the angle at which the wing meets the particles of air in the free airstream.

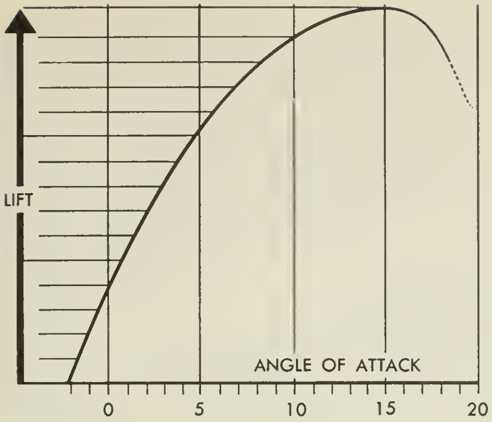
High angle of attack may be used to compensate for the decrease in air velocity when flying at slow speeds. However, as the angle of attack increases, drag-due-to-lift and pressure drag both increase. So an excessive angle of attack can easily result in a "stall."



Methods of changing camber.

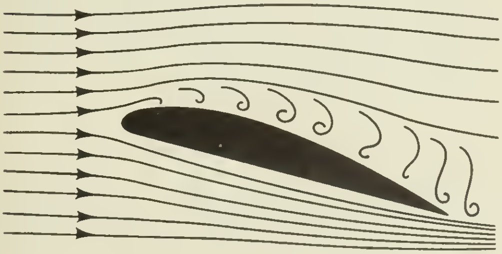
THE STALL

As the angle of attack is increased (keeping airspeed constant), the wing will produce more and more lift, but only up to a certain point.



Relationship between angle of attack and lift (for a specific wing).

The reason is that, as the angle of attack is increased, the boundary layer is no longer able to flow smoothly over the wing, but begins to break away from the surface. This results in turbulence and destruction of the laminar flow. The drag increases markedly, the air speed will tend to decrease, vibrations may be heard or even felt in the aircraft, and part of the lift will be lost. If the angle of attack is increased further, separation of the airflow from the wing surface may become complete and the plane will "stall."[6] The wing in the adjacent illustration is approaching the stall condition. Here is a full stall.



One often hears the term "normal stalling speed," which is supposed to refer to the slowest airspeed at which certain aircraft can fly. However, stalling speed is not the same under all conditions even for the same aircraft. It depends upon the load, the distribution of the load within the plane, the density of the air (which depends on air temperature and barometric pressure), and many other factors. A pilot must learn to recognize changes in the "feel" of the controls and to hear the vibrations (caused by turbulence in the boundary layer and on the tail surfaces) that precede a stall.

Correcting a stall in flight is a simple matter of pushing the nose of the plane down. This will decrease the angle of attack and increase the airspeed thereby regaining sufficient lift force to keep the plane flying.

HIGH SPEED FLIGHT

Many years before aircraft began to fly at speeds faster than sound, designers were faced with questions of supersonic aerodynamics. As early as 1775, experimenters were studying drag on high-speed gunnery projectiles, and by 1900 engineers were already discussing problems which arose when steam turbines turned at supersonic speeds. By 1926, designers of propellers for racing planes had already become increasingly concerned with the effects of propeller-tips moving faster than sound.

As an airplane approaches the speed of sound, the air flowing around the wing may actually exceed the speed of sound. At such velocities, the behavior of the air changes radically. Aircraft which fly near or above the speed of sound therefore require quite different design characteristics for efficient flight. To understand what happens at such speeds, we must first examine what is meant by "the speed of sound."

The Mach Number

The speed of sound is so important to the designers of high-performance aircraft that airspeed is measured relative to it. The

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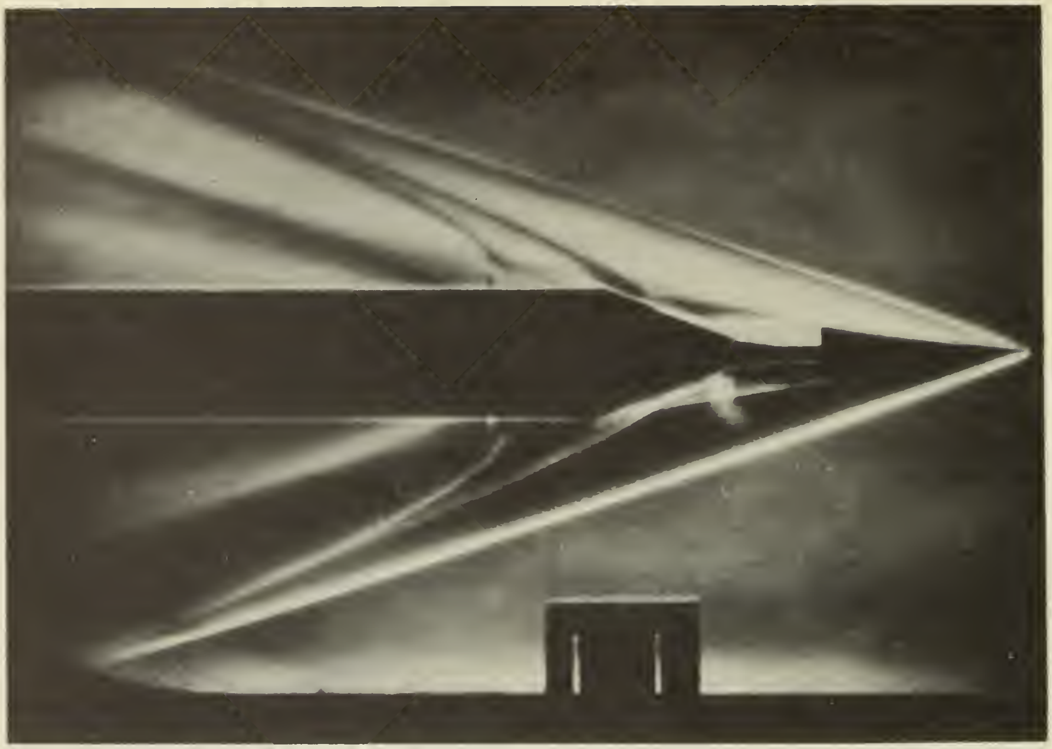
[6] Even in a complete stall, all the lift is not lost. If it were, the plane would drop like a rock. In fact, only about 10 percent of the lift is destroyed in a full stall. The plane may lose altitude very rapidly but it does not exactly "fall."



U. S. Air Force Photo

Photograph of shock wave pattern around a 10-degree wedge. The velocity of the airstream moving through the test section and around the wedge is Mach 5.0 or nearly 4,000 mph.

speed of sound is generally said to be 760 miles per hour. An aircraft flying 760 mph at sea level on a standard day is flying at Mach 1.0. A speed of Mach 2.0 would be 1,520 mph.

But the speed of sound varies with the temperature of the air. At 20,000 feet, where the air is much colder than at sea level, the speed of sound (Mach 1.0) is about 706 mph, and Mach 2.0 would be equal to 1,412 mph. Mach 0.85 would be 600 mph, and Mach 0.71 would be 500 mph.

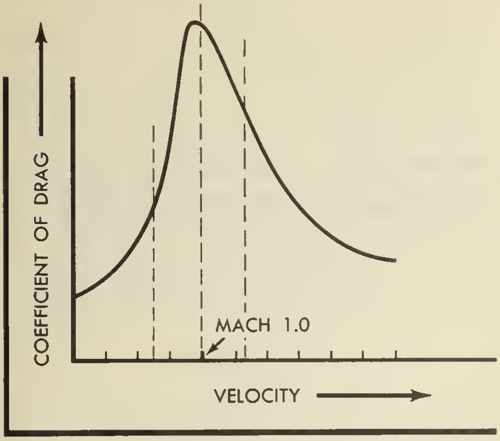
From 30,000 feet to 100,000 feet, the air temperature is nearly constant and Mach 1.0 is roughly 660 mph. Above 100,000 feet the temperature begins to rise and the speed of sound increases with altitude.

The temperature of the air may vary at different points around an aircraft because of differences in air velocity at these points. Thus Mach 1.0 may have one value at a point on the upper surface of the wing, another value at the side of fuselage near the tail, and yet another at the leading edge of the fin. This results in different behavior of the air at different places.

When an aircraft is flying at a speed such that the airflow is subsonic in some places and supersonic in others, it is said to be flying in the *transonic* range. This is usually from about Mach 0.9 to 1.4.

The "Sound Barrier"

There was a period in the history of aviation during which the fastest planes available could nearly attain, but rarely exceed Mach 1.0. These planes had considerable difficulty "penetrating the sound barrier." The following diagram shows the drag coefficient of a bullet. The curve is not drawn to scale and, of course, applies to a much simpler situation than is presented by an aircraft, but it does demonstrate very clearly the relationship between drag and Mach number.[7]



Notice the sudden rise of the drag coefficient at velocities just below Mach 1.0, and the gradual decreases above Mach 1.0. The *actual* drag is proportional to the drag coefficient multiplied by the velocity squared. The actual drag continues to rise above Mach 1.0, but not nearly so fast.

Another disconcerting characteristic of transonic flight is the instability of the shock waves. In the transonic range, shocks form on the upper and then on the lower surface of the wings, but their positions vary unpredictably. They come and go, skittering rapidly back and forth across the wing. This contributes to the severe problems of stability and control at transonic velocities. At supersonic speeds, the shock waves are stabilized in fixed positions and can be allowed for by the aircraft designer.

Modern aircraft are now designed and built to go through the transonic region rapidly and easily. Supersonic flight has become a practical reality, for many of the worst problems of transonic flight—tremendous drag, buffeting, uncertainty of control, and so on—disappear or are sharply reduced at truly supersonic speeds.

Compression Waves

In our earlier discussion of lift, it was shown how pressure patterns are sent out ahead of a wing. These pressure patterns result in air movement which assists in maintaining the "circulation" around the wing. You will recall that the pressure pulses which cause this air movement travel through the air at the speed of sound.

It is a simple matter to calculate how fast these pressures travel relative to the plane. All we need do is subtract the plane's airspeed from the local speed of sound. Consider a plane at 20,000 feet. We may suppose the local Mach 1.0 to be equal to 700 mph. If our plane is flying 500 mph, the pressures are sent out ahead at 200 mph. Now, over any appreciable amount of time, air pressures moving at 200 mph can go a considerable distance, and travel quite far ahead of the plane.

But what happens when the plane is traveling 800 mph? Remember, the speed of sound is determined solely by the characteristics of the *air it is traveling in,* and is not affected by anything the *source* may be doing. So now, when the wing sends out a pressure pulse, the plane passes it up at the rate of 100 mph. The air in front of the wing has received no "warning" at all, but is standing quite still—totally unprepared for the arrival of the wing. When the wing hits it, this air tries to move away and flow around the wing, but the air next to it can't move away fast enough to give it space to move into. As a result, the air struck by the wing is compressed violently. The result is a "shock wave," or more precisely a "compression wave."

This compression wave is a kind of pressure pulse, but it does not act quite as sound does. For one thing, it travels faster than sound—the stronger the shock, the faster it travels. For another, a shock wave can result in tremendous drag on the aircraft.

The illustration shows the kind of oblique shock waves formed at the leading edge of a wedge-shaped wing at Mach 1.5. Notice

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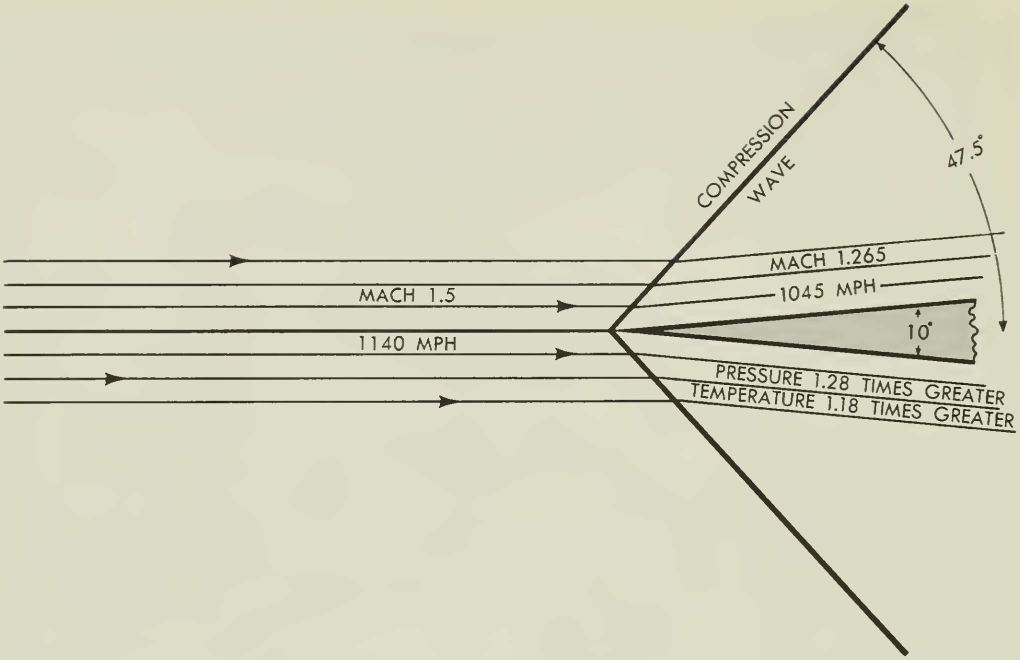
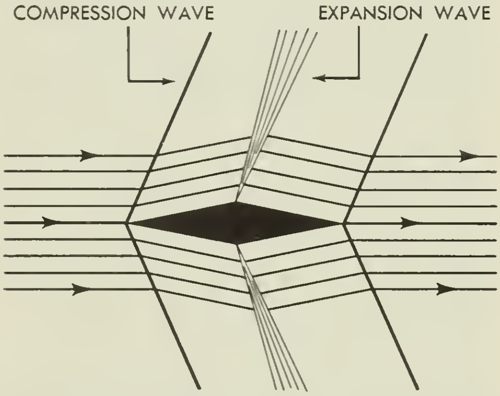
[7] Adapted from O. G. Sutton, *The Science of Flight,* Penguin Books, Ltd., 1955, p. 160.



that the air is compressed, and that the air velocity decreases behind the shock. At the same time, its temperature and pressure increase. Whenever air travelling at sonic speed or higher must enter a volume smaller than it has been occupying, a compression wave results.

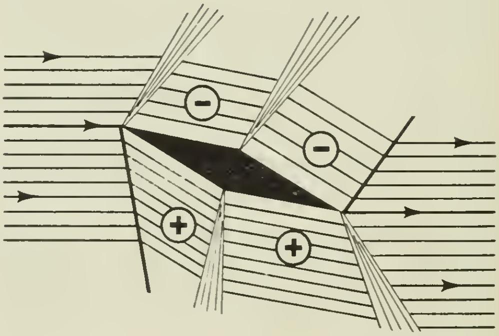


A diamond-shaped wing demonstrates very well some further effects at supersonic speeds. After the air passes over the front half of the wing, it encounters a corner and is suddenly required to expand into a greater volume. Whenever this happens, an *expansion wave* occurs. Because of its shape in two-dimensional pictures, it is sometimes called an "expansion fan." When air passes through this fan, its velocity increases and its temperature and pressure decrease.

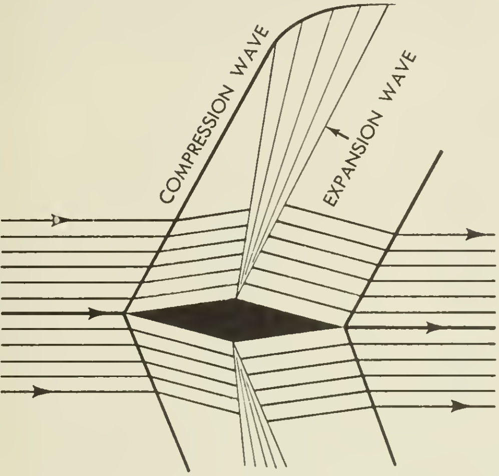
At the trailing edge of the wing, the air is again forced to compress and another compression wave occurs.

Lift at Supersonic Speeds

If the wing is to provide lift, there must be a high-pressure area below it. The illustration below shows what happens when the diamond-shaped wing is given an angle of attack.



The diamond-shaped airfoil provides a clear example of how a high-pressure area can be created on its under surface. The plus and minus marks show high and low pressure areas. In this case, the angle of attack is so great that an expansion wave occurs at the top of the leading edge and behind the trailing edge. This is, of course, an exaggerated example. In the next diagram we see a somewhat more realistic situation.



There is higher pressure below the wing than above it. Note the central flow lines, which have been drawn especially heavy. Part of the passing air has been displaced downward. As before, it is reaction to the downward velocity imparted to the air which provides the lift force. Because of the tremendous velocity and the consequently great amount of air displaced over a period of time, the angle of attack can be very small indeed at supersonic speeds. This low angle of attack accounts for the low value of the drag-due-to-lift at supersonic velocities.

Interference of Shock Waves

Compression waves and expansion waves are exact opposites in many respects.

When they meet, they tend to cancel each other. In the last illustration, the waves have been extended to show their intersection. The compression wave is the stronger of the two, but it is weakened and curved back by the effect of the expansion wave.

Even the best wing design does not eliminate shock waves: any object which is thrust through the air at Mach 1.0 or faster will produce shocks. This is true of the wings, tail, nose, canopy, or anything that meets the airstream. Even a well-designed aircraft flying at supersonic speed may be producing up to 100 or more shock waves on its various parts. Some of these will be quite weak. Others will be very strong. Many will be interfering with each other. By proper design, adequate control and stability can be maintained and drag can be kept to a minimum.

The Area Progression Rule

One of the most widely publicized design features of modern high-speed aircraft is the slimming of the fuselage at the point of greatest wing thickness. This feature is an application of the "Area Rule" or "Area Progression Rule," and is a feature of the design of the F–100, F–101, F–102, F–106, B–58, and other planes. Greatly simplified,

U. S. Air Force Photo

▲ North American F–100A "Super Sabre."

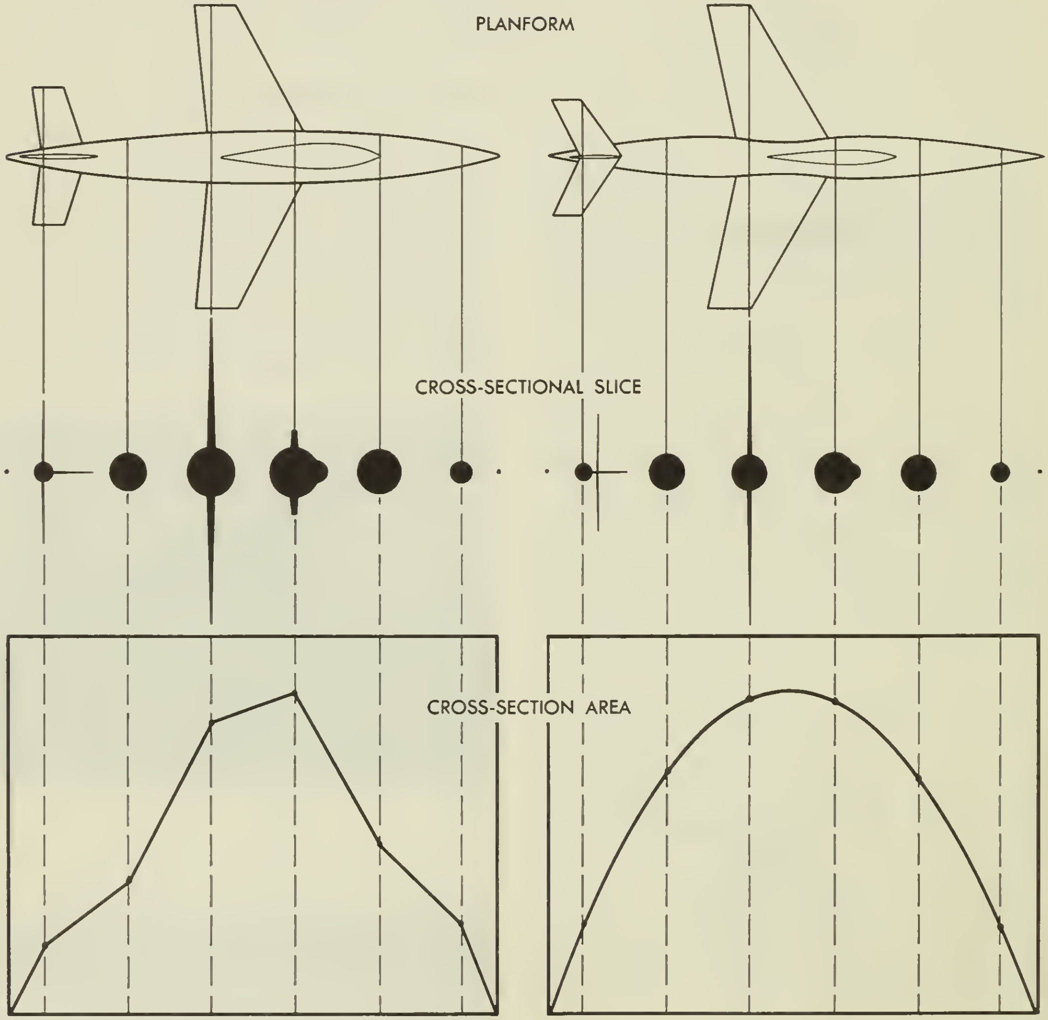
Convair B–58 "Hustler." ▼

U. S. Air Force Photo

the area rule states that near Mach 1.0 drag on an aircraft is least when its cross-sectional area is least, and when the increases or decreases in cross-sectional area from front to back are smooth. Consider the hypothetical examples here.

The area rule, once considered a very significant factor in reducing the problems and hazards of high-speed flight, is no longer of major importance in designing an aircraft. At best, it provides only a partial solution to the problems it is meant to solve, and is successful only between Mach 0.9 and 1.4.

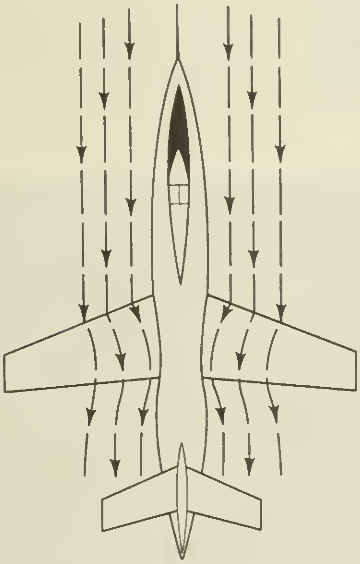
In recent years, tremendous advances in design of high-speed aircraft have established their reliability and safety. Supersonic aircraft no longer require superhuman pilots. Careful training is certainly necessary. But the days when only the most courageous or foolhardy attempted supersonic flight are gone with the days when those adjectives were applied with equal vigor to the leather-jacketed biplane pilots of yesteryear.



In old designs (left) the cross-sectional area changes irregularly and abruptly from nose to tail. The area rule requires smooth, symmetrical changes in cross-sectional area as at the right.

The "Coke-Bottle Fuselage"

Another well-publicized design characteristic of some high-performance aircraft is the so-called "coke-bottle fuselage" or "wasp-waist." This is a pinching-in of the fuselage near the trailing edge of the wing. It has the effect of reducing certain problems that occur at transonic speeds in aircraft such as the F-86-D. The basic reason, which is related to the way air flows over a swept-back wing, can be deduced from the greatly simplified and exaggerated diagram below.



The Sonic Boom

A shock wave, like a sound wave, decreases in strength as it spreads away from the plane. As its strength fades, it slows down to the speed of sound and becomes a thunderlike boom. However, if the plane is flying low enough, the shock wave itself will be heard by a person on the ground as the edge of the cone passes him. This sharp explosionlike sound is called a *sonic boom.* A sonic boom or the sound waves it turns into can be heard 5 or 10 miles away. Since high-speed aircraft typically fly at altitudes 4 or more miles up, the booms are usually quite weak by the time they reach the ground.

A high-speed jet, even when it is flying too slowly to produce shocks, makes a tremendous amount of noise. Frequently this noise is first heard quite suddenly as the plane approaches a listener on the ground, and it may seem almost like an explosion. Its apparently sudden start sometimes makes people think they have heard a sonic boom. This noise, however, fades slowly as the plane disappears, and is usually nothing more than the normal roar of the aircraft. Another sound that is sometimes mistaken for a sonic boom is the explosive roar that results when a jet pilot starts the afterburner.

"The Thermal Thicket"

The so-called "sound barrier" that once puzzled aircraft designers is no longer a barrier at all. Now the engineers and scientists are turning their attention to a new problem which must be solved as aircraft are designed for even greater speeds. The problem, popularly called "the thermal thicket," concerns the searing temperatures created by an object flying through the air at extremely high speed. This heat results from ram compression of the air by the fast-moving aircraft, and is similar to the heat created by compression of the air in an ordinary tire pump.

You will recall that there is a very thin layer of air which tends to stick with the skin of the aircraft and travel along with it. Considered from the aircraft, this layer, the boundary layer, has almost no velocity at all. It has been brought to a nearly complete halt from its original, tremendous velocity. Its energy has been converted from velocity to heat.

About a third of all the heat generated is carried away by the rushing air just outside the boundary layer, and more is radiated away. But the rest goes into the skin of the aircraft, causing a considerable rise in the temperature of the metal.

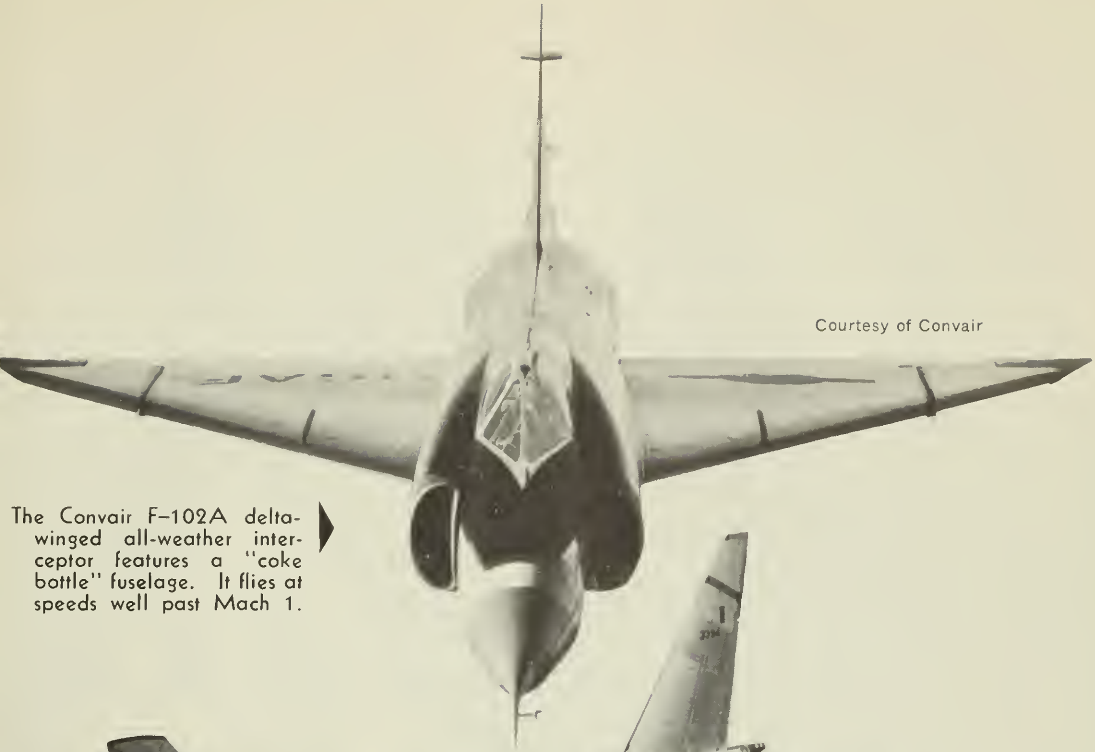
The amount of heat generated at extremely high speeds can be seen in the example of a plane flying at 28,000 feet where the temperature of the air is −40° F. Mach 1.0 here is 684 mph. At Mach 2.0 (1,370 mph), the boundary layer temperature may rise above 250° F., and at Mach 3.0 (2,050 mph) it is well above 600° F. If the skin itself were ever to reach this temperature, it would cause prodigious problems. Almost all the materials which are practical for use in building aircraft show great losses in their structural strength at such high temperatures. Only such materials as toughened glass, titanium alloys, and stainless steel meet the strength requirements for an aircraft skin which must endure this tremendous heat for any length of time, and their use in aircraft manufacture raises engineering problems of great complexity.

The problem is certainly not insoluble. Even with present materials, very brief flights are possible at extremely high Mach numbers, particularly if they occur at extremely high altitudes. The heat collected in a short period of time can be absorbed by heavy machinery in the craft (or even by the fuel supply), and some can be radiated away. It is therefore comparatively easy to design missiles for speeds many times that of sound.

Extremely high speeds can be reached and maintained if we go high enough where the air temperature and density are very low. Someday, using extensive refrigeration and new heat-resisting materials, long-range aircraft will almost certainly fly at speeds as high as Mach 18 or 20.

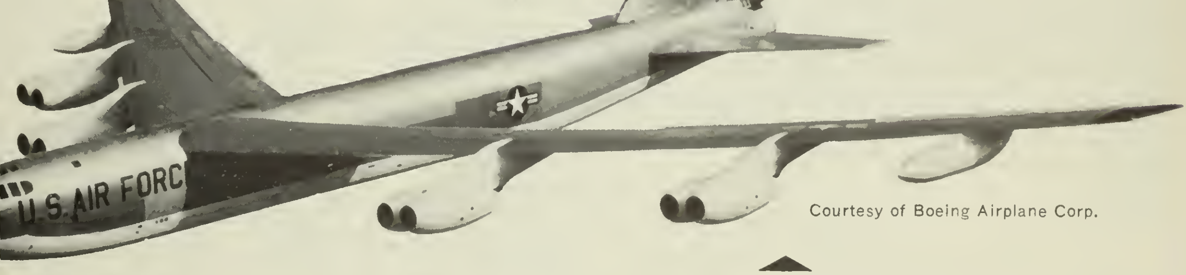
U. S. Air Force Photo

Constructed largely of titanium to resist heating, the Douglass X-3 was designed for sustained flight at Mach 3.0 to study problems of the heat barrier.



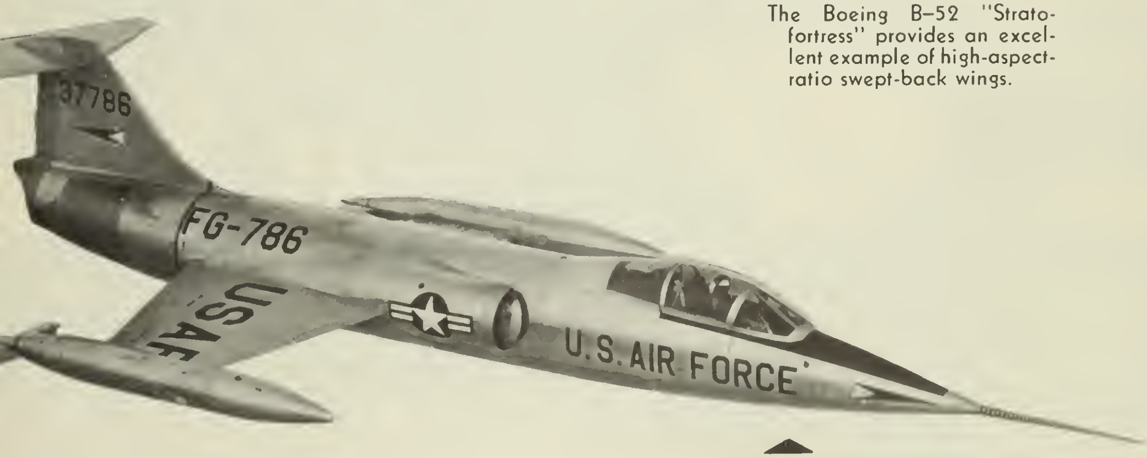
Courtesy of Convair

The Convair F–102A delta-winged all-weather interceptor features a "coke bottle" fuselage. It flies at speeds well past Mach 1.



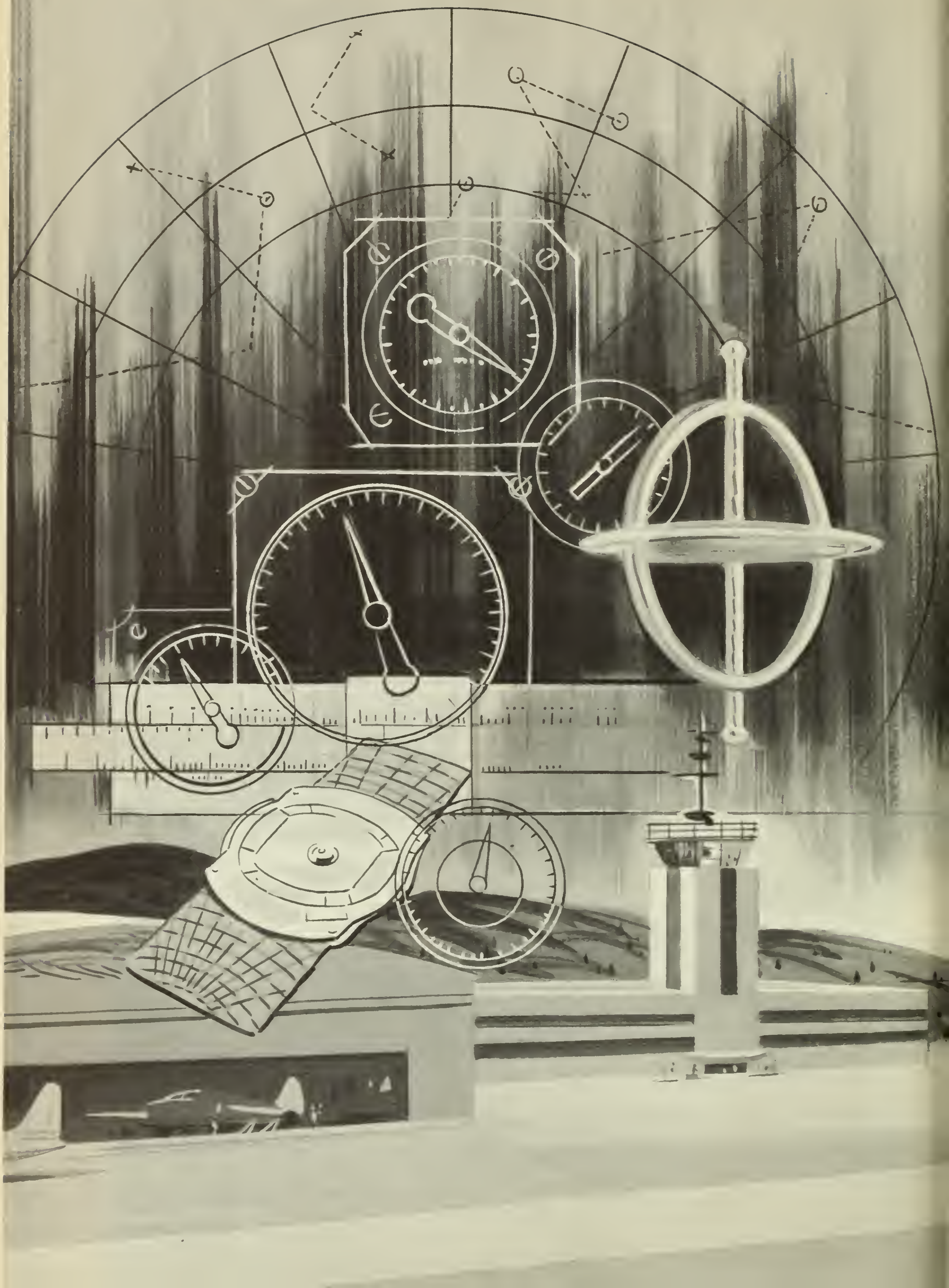
Courtesy of Boeing Airplane Corp.

The Boeing B–52 "Stratofortress" provides an excellent example of high-aspect-ratio swept-back wings.



U. S. Air Force Photo

Compare the low aspect ratio and the wing-span of the F–104A "Starfighter" with those of the B–52 above.



PART 2

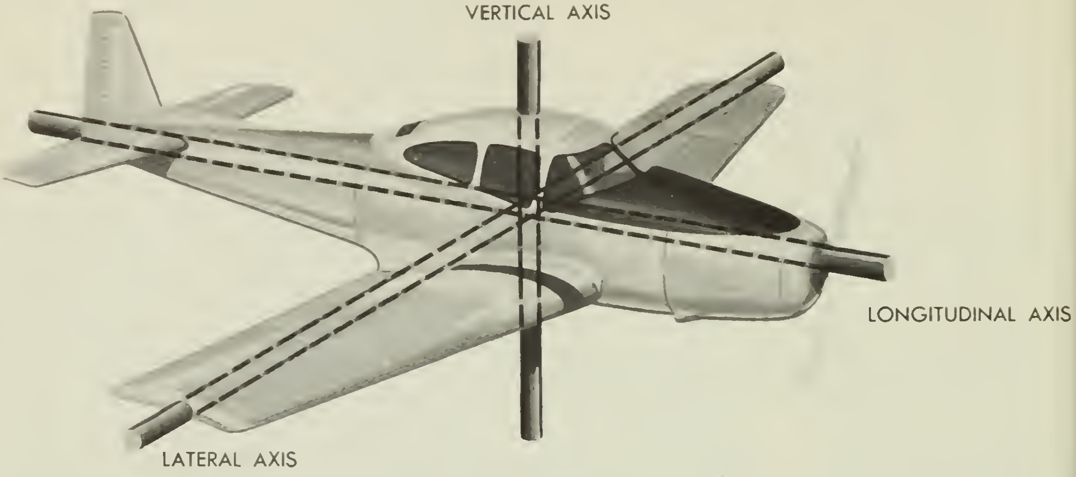
CHAPTER 9

Stability, Control, Navigation and Guidance

A STABLE AIRCRAFT is one which tends to maintain straight and level flight without undue attention from the pilot. It is designed in such a way that it "wants" to stay level and on course and will make its own minor corrections when temporary disturbances such as gusts of wind tend to make it pitch, roll, or turn.

If the disturbances which work upon the plane are too great to be corrected by the plane's natural stability, and the pilot must force the plane to return to the straight and level, that is control. Or if the pilot wishes the plane to deviate from straight and level flight and *makes* it turn, climb, roll, dive, accelerate, or decelerate, that is also control.

When the pilot sets and maintains the plane's direction in a way that will take him from one airfield to another, corrects his heading so that the winds will not take him elsewhere, and generally controls the plane so that it arrives where and when he desires, that is navigation.



Axes of rotation of an aircraft.

And when devices are provided which will do some or all of the navigation work, plus some or all of the control work, that is guidance.

STABILITY

When climbing, a plane is said to be in a "nose-up attitude;" when banking, it is in a "wing-low attitude," and so on. The word *attitude* refers to the kind of "posture" or "stance" a plane assumes relative to the ground.

All the possible changes of attitude of an aircraft can be analyzed into rotations around its three axes. The three axes of rotation are shown in the illustration. They normally cross at the balance point or *center of gravity* of the plane. Rotation around the lateral axis (an imaginary line which runs from wingtip to wingtip) is called *pitch*. Rotation around the longitudinal axis (which runs from the nose to the tail) is called *roll*. And rotation around the vertical axis (which runs up and down through the plane's center of gravity) is called *yaw*.

All modern aircraft are designed with certain characteristics which provide built-in stability of attitude.

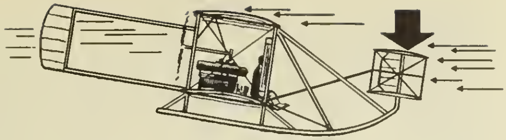
Stability in an Arrow

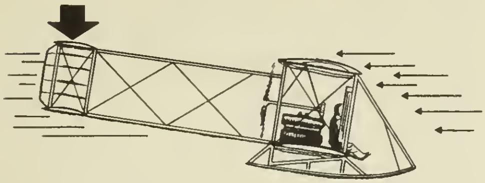
There are two important reasons why an arrow flies straight. The first is that its metal tip places the arrow's center of gravity fairly well forward with most of the shaft trailing behind. The second reason is the position of the feathers at the end. In effect, the feathers are at the end of a long lever, and their weather-vane action keeps the arrow pointed straight into the wind.

The stabilizer surfaces of an airplane are similarly placed at the end of a long lever, the fuselage. And the center of gravity of the aircraft is located well in front. In a conventional light plane, the engine is located in the nose with the passengers directly behind. Such a plane achieves its stability of direction relative to the wind just as an arrow does.

The early Wright planes had the elevators in front. This created a very unstable machine. If the plane were to pitch down slightly, the effect was to make the plane pitch down still more.

But when the elevators were put at the back, a slight pitching down caused the wind itself to force the plane back into straight flight.



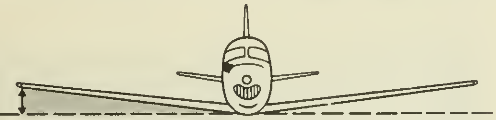


tability in Pitch and Airspeed

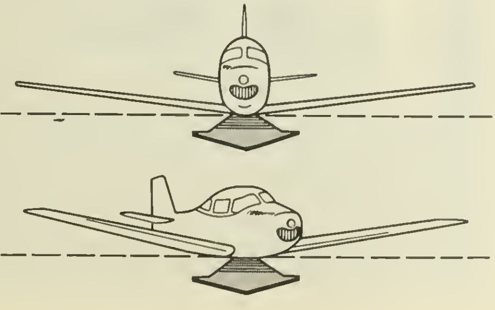
A stable aircraft will seek a definite airpeed and pitch depending on its trim and hrottle setting. Suppose, for example, that sudden gust results in a nose-down attiude. The plane will dive slightly, gaining peed. As its speed increases, the lift creted by the wing increases and tends to ring the nose back up. Bringing the nose p decreases the airspeed and the plane ssumes its former airspeed and pitch.

tability Against Sideslip

A common feature of aircraft is a slight p-slant of the wings called dihedral. If we



xaggerate this angle, we can see how it rovides stability against sideslip. If the lane begins to move sideways to the right, he angle of attack on the right wing is increased. This increases the lift on that wing nd it rises, rolling the plane to the left and topping the sideslip.



Both planes (below left) are flying directly toward you. The lower aircraft is sideslipping toward you. You can see that the angle of attack is appreciably increased on its right wing. The result is that the plane rolls to stop the slip.

But in a bank, the plane will tend to lose altitude because its lift force is no longer opposing gravity directly. It slips down a bit to its left, the dihedral effect operates again, and the plane rolls back to a level attitude.

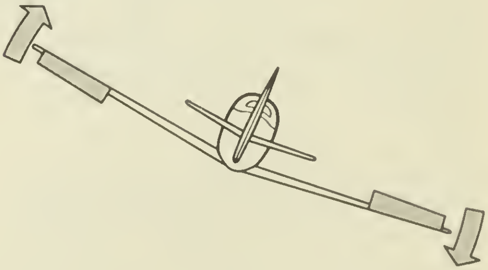
CONTROL

The controls of an aircraft were listed and described in an earlier chapter. There are four: rudder, elevator, ailerons, and the propulsion system. All four may be seen at work in a simple turn.

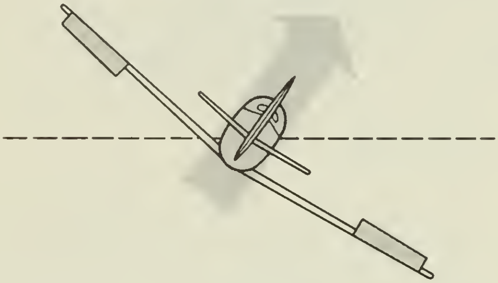
A boat is turned simply by use of a rudder. But in an airplane rudder action alone will merely cause the plane to yaw and sideslip, the nose may drop from loss of lift as the dihedral causes a roll, and the plane may go into a spiral dive. To the novice, it seems that the pilot need only correct this tendency by banking further into the turn, but in fact, the process is far more complex aerodynamically. An airplane turns by coordinated use of all four controls.

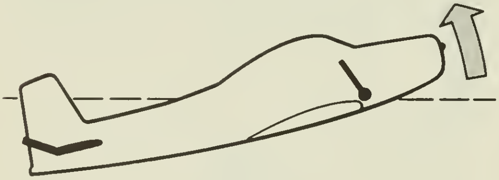
The four operations involved in turning are all performed simultaneously but in varying amounts during the maneuver. For simplicity, we shall analyze them as though they they were performed separately. The example is a right turn.

The pilot presses the stick to the right. This causes the right aileron to rise, reducing the lift on the right wing.



At the same time the left aileron hinges downward, giving increased lift to the left wing. The plane therefore begins to roll (or "bank") to the right, and will continue to roll until the stick is returned to neutral and the ailerons are thereby returned to their normal positions. The steeper the bank, the tighter a properly coordinated turn will be. As the desired degree of bank is approached, the pilot eases the ailerons back to normal. The plane will then stay in that degree of bank until rolled back to the left.



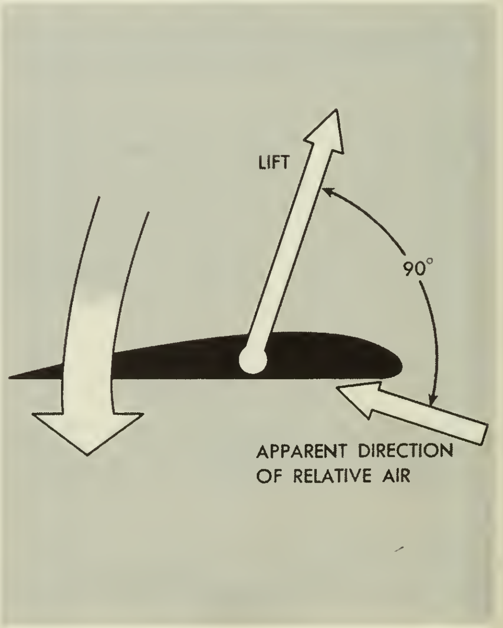


As the roll begins, the wings assume an angle to the force of gravity. Part of their lift force then begins to pull in the direction of the turn, and there is a decrease in the amount of upward lift. This decrease tends to let the plane lose altitude during the turn, so that a spiral dive might result. An increase in the lift force is therefore necessary to hold constant altitude. This can be achieved by increasing the angle of attack. So the pilot presses back on the stick. This raises the elevators and forces the nose up and to the right increasing the angle of attack to the point where the upward component of the lift is sufficient to maintain altitude. Of course, the turning component of the lift force is also increased by this action, so that the plane turns to the right. From this it can be seen that the principal force causing the plane to turn is the *lift* force, and that the lift force is increased by elevator action.

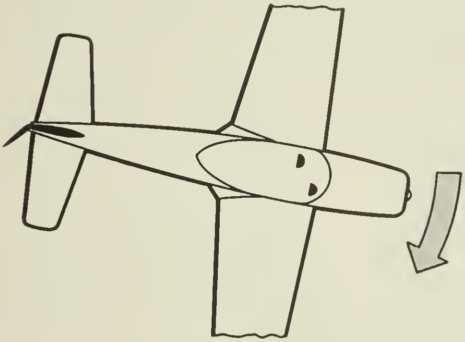
But nature never gives something for nothing. If the lift force is increased, the amount of the increase must come from somewhere. It comes from the plane's momentum, and the airspeed drops. This can be compensated by advancing the throttle slightly during the turn. In a really steep turn, this may be absolutely necessary, for as the lift increases, so does the drag, and the powerplant is the only source of additional thrust to balance the increased drag.

Work must be done just to change the direction of the plane. A plane in a turn is like any other mass on the rim of a wheel. The natural tendency, because of the centrifugal force, is to fly off the wheel at a tangent. The turning component of the lift force is called upon to overcome this and keep the plane turning.

While the plane is rolling into its bank, the right wing is descending in the airstream. In effect, therefore, the angle of attack is increased. As viewed from the wing, the air seems to be arriving from a direction in front and below. The descending wing meets the air this way.



Since the lift force is alway perpendicular to the relative airstream, it is now pulling the wing *forward* as well as up. This is not happening to the left wing. Indeed, the reverse is happening. So the forward component of the lift force on the right wing tends to pull the nose of the plane around to the left and make the plane yaw out of the turn. The pilot corrects this tendency by pressing the right rudder pedal, swinging the rudder to the right. The airstream works upon the rudder, moving the tail of the plane to the left, and forcing the nose around into the direction of the turn.[1]

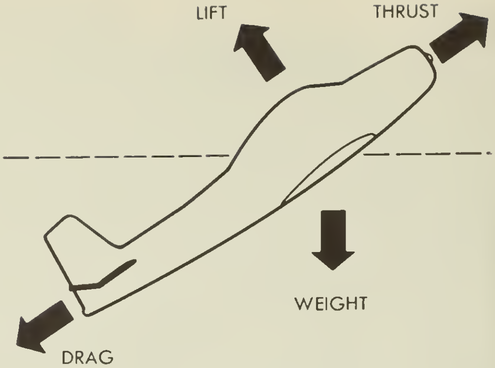


Once the plane is turning properly, the ailerons and the rudder must be returned to neutral (or near neutral) and a steady turn is maintained by use of the elevators alone (back pressure on the stick). Rolling out of the turn is accomplished by coordinated and simultaneous use of all three controls again, but this time in the opposite direction.

The coordination of aileron, elevator, rudder and throttle to achieve a smooth turn without skidding, slipping, or losing altitude is one of the first things a pilot learns.

Climbing and Descending

Climbing is not a simple matter of pointing the nose up. In fact, merely pointing the nose up is ordinarily a very inefficient way of gaining altitude. It is true, of course,



that lift is increased by an increase in the angle of attack, and that the nose must be raised to increase the angle of attack. But lifting something always requires an expenditure of energy, and the only sources of the required energy are the engine and the momentum of the plane. If the nose is pulled up without the addition of power from the engine, momentum will raise the plane a little. But drawing energy out of the plane's momentum necessarily results in a reduction of airspeed. Thus, while slight changes in altitude can usually be made safely with the elevators alone, it is dangerous to consider them as the altitude control.

Generally speaking, it is far wiser to think of the throttle as the principal altitude control, rather than the elevators. This is particularly true at critical times such as landing or taking off. The natural impulse of the beginner who finds that he is going to land short of the field is to pull back on the stick. But at the slow airspeed used in landing, borrowing energy out of the plane's momentum to use for climbing may reduce the airspeed so much as to cause a stall—and a stall at low altitude can easily lead to a crash. The wise pilot therefore considers the *throttle* as the altitude control and draws the additional energy needed for climb purposes from the engine.

The elevators, then, become *airspeed controls*. The truth of this can be seen when we again consider the stall. The only way to prevent a stall is to increase airspeed. The simplest and surest way to do this is to lower the nose. This will always increase

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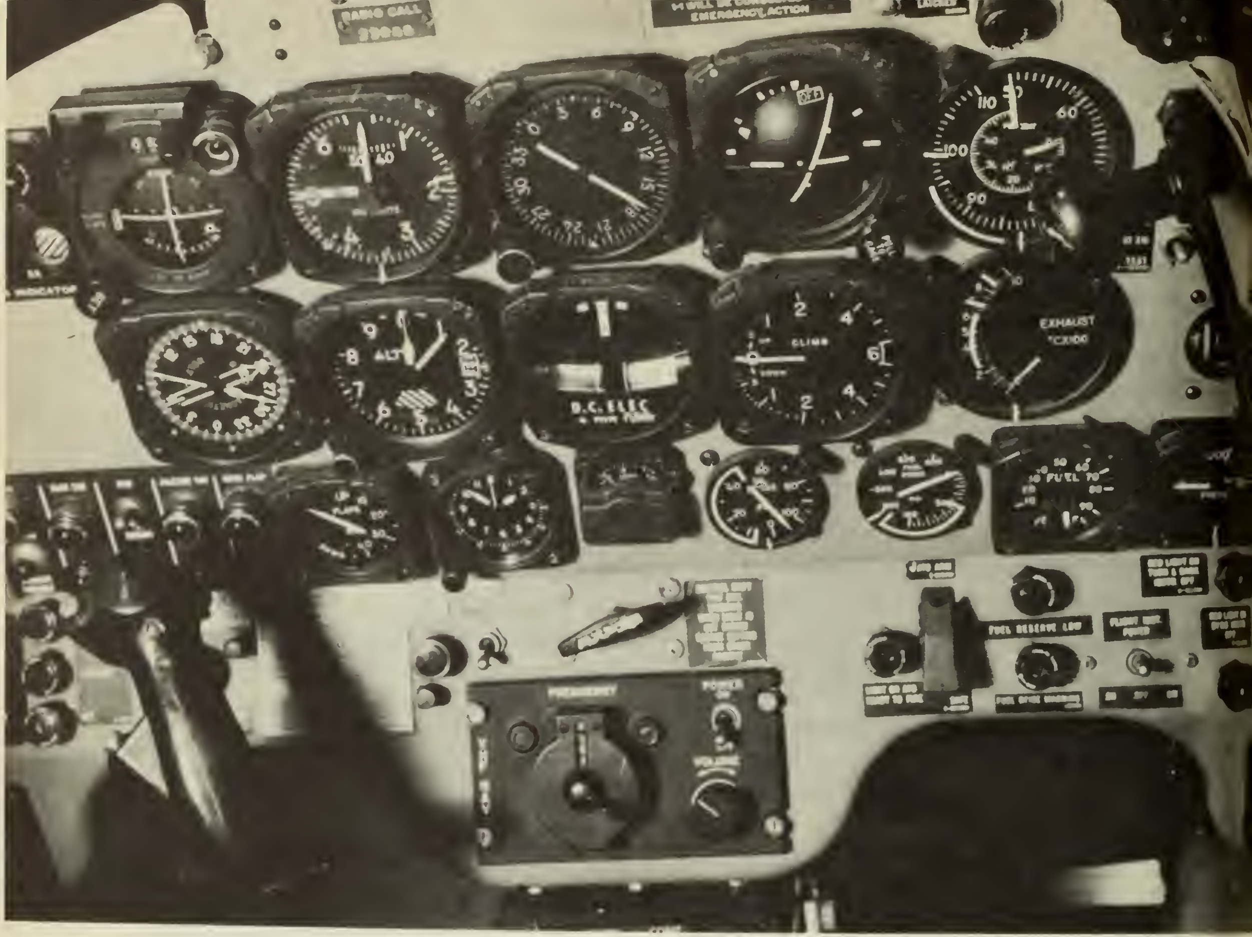
[1] In most planes of modern design, improved design has eliminated much or all of this yaw effect. Turns may, therefore, be made with very little rudder action or none at all.



Instrument panel in the front cockpit of an Air Force T-33 jet trainer. A similar panel is located in the rear cockpit.

U. S. Air Force P

airspeed. The throttle can often be used to increase airspeed, but not when the engine is already putting out its maximum power. Furthermore, an increase in thrust usually causes the nose to rise somewhat, and this may actually contribute to the stall.

AIRCRAFT INSTRUMENTS

The complex array of instruments in a modern aircraft appears bewildering to the uninitiated. But when it is realized that the pilot need not watch all the instruments at once, and that they are grouped according to their various functions, the instrument panel seems much simpler and not at all confusing.

Engine Instruments

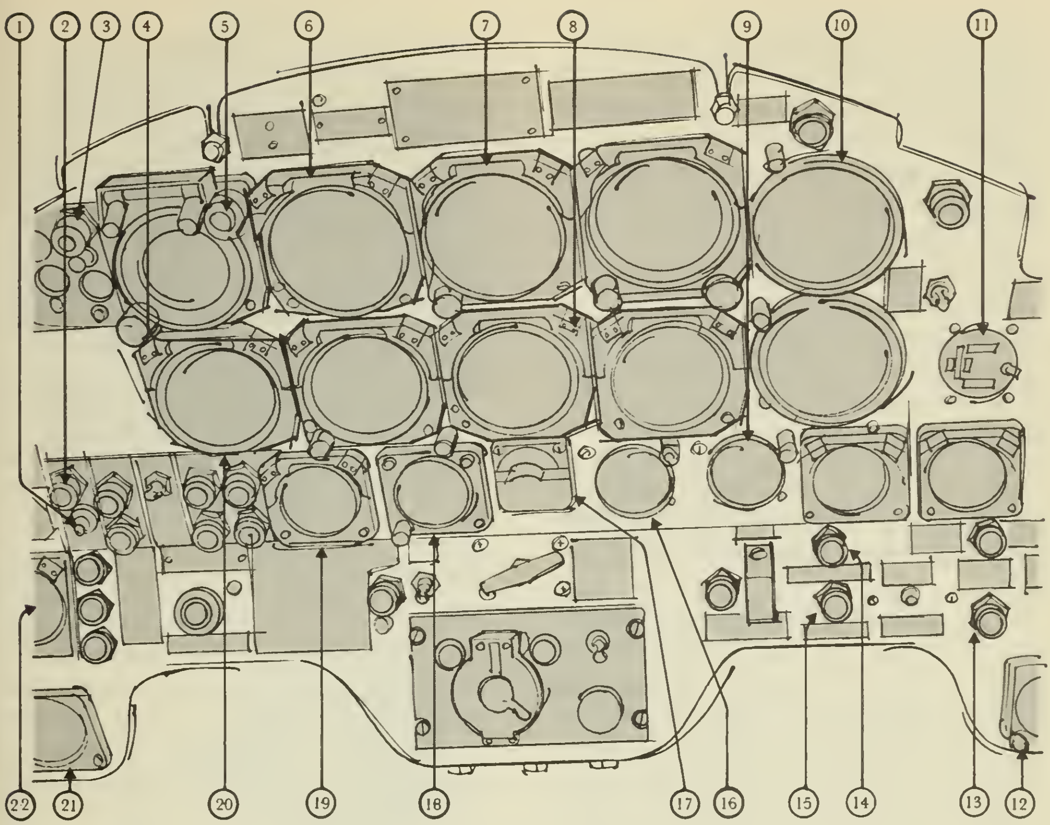
Several of the instruments on the panel indicate various aspects of engine operation.

Equipment Indicators

Also on the control panel are indicators which tell the pilot whether the landing gear is up or down, whether or not the flaps are down and how far, if the engine cowlings are open, and so on.

Flight and Navigation Instruments

The basic flight instruments are the altimeter, airspeed meter, compass, and attitude indicator. The altimeter not only tells the pilot approximately how high he is above sea level, but whether he is climbing or descending. The airspeed meter tells the pilot approximately how fast he is going (and, indirectly, how much lift he has available).



Based on TO IT-33A-1

INSTRUMENT PANEL, FRONT COCKPIT

1. **Student lockout button**
2. **Speed brake telltale indicator light**
3. **Landing gear unsafe warning light**
4. **Altimeter**
5. **Marker beacon indicator**
6. **Airspeed indicator**
7. **Directional indicator**
8. **Turn and slip indicator**
9. **Engine fuel pressure gage**
10. **Engine techometer**
11. **Fuel quantity counter**
12. **Accelerometer**
13. **Gyro instrument warning light**
14. **Fuselage tank low level indicator**
15. **Fuel de-ice warning light**
16. **Engine oil pressure gage**
17. **Generator load meter**
18. **Clock**
19. **Wing flap position indicator**
20. **Radio magnetic indicator**
21. **Cabin pressure altitude indicator**
22. **Oxygen pressure gage**

It also indirectly indicates pitch, for if the plane's nose is inadvertently pulled up, the airspeed will tend to decrease, and if it is nosed down, airspeed will tend to increase.

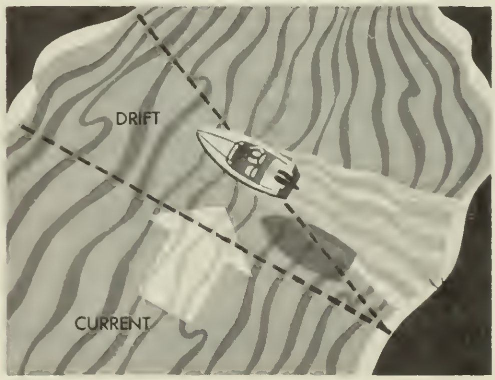
The compass tells the pilot the direction of the plane's heading and also whether the plane is turning. Because rate of turn depends upon rate of bank, it also indirectly indicates bank. Nearly all planes are equipped with ordinary magnetic compasses, but the reaction of this instrument during a turn is quite slow. Modern aircraft therefore usually have an additional instrument called a "heading indicator" which is stabilized by a gyroscope. Such an instrument reacts instantly to any change of heading. However, gyroscopes have a tendency to precess (drift), and the heading indicator (or "directional gyro") must therefore be reset to correspond to the magnetic compass about every 15 minutes.

The attitude of the plane is shown by another gyro-stabilized instrument—the attitude indicator. It shows both pitch and roll.

If we add a clock and a free air temperature gauge to these four instruments, we have the basic instruments necessary for flight and navigation. The clock is used to measure the elapse of time (between check points for example) and therefore to compute such things as ground speed, time of arrival, and fuel consumption. The temperature gauge reading is necessary to correct for errors in the other instruments, and to detemine the best engine settings.

NAVIGATION SYSTEMS

The atmosphere through which an aircraft flies is hardly ever completely still. The air mass is usually moving relative to the earth and the plane is flying in the air mass. Thus, like a boat headed across a river, it drifts with the stream. This situation presents the basic problem of air navigation whether the aircraft is manned or unmanned. Because of wind, an aircraft seldom goes exactly where it is headed or at a ground speed exactly equal to its airspeed.



An aircraft headed due north at 100 mph against a north wind of 10 mph will travel only 90 mph over the ground. If the 10-mph wind is from the south, the plane will travel 110 mph over the ground. And if the wind is from the northwest, the plane's path over the ground (usually called the plane's *track*[3]) will be slower than its airspeed and, in addition, will be blown east of its north heading.

Exactly how such problems are solved is the topic of the AFROTC course in Air Navigation. There it will be seen that the solution to nearly all navigation problems lies in a computational technique known as "dead reckoning" or DR (sometimes written D/R). All the instruments and devices concerned with navigation are designed either to assist the pilot or navigator in making his DR calculations, or to do some or all of them for him.

At the high speeds of some aircraft even as early as World War II, the time required merely for the arithmetic of navigation became an embarrassment. By the time a navigator or pilot had figured out where he was, he was far away from there. The first developments to alleviate this situation were mechanical computers similar to sliderules. With these, computational time was effectively reduced.

But as speeds increased with advent of jets, even the manipulation of such old and faithful aids as the E6B consumed too much time. Military aircraft began to carry mechanical and electronic computers of various kinds.

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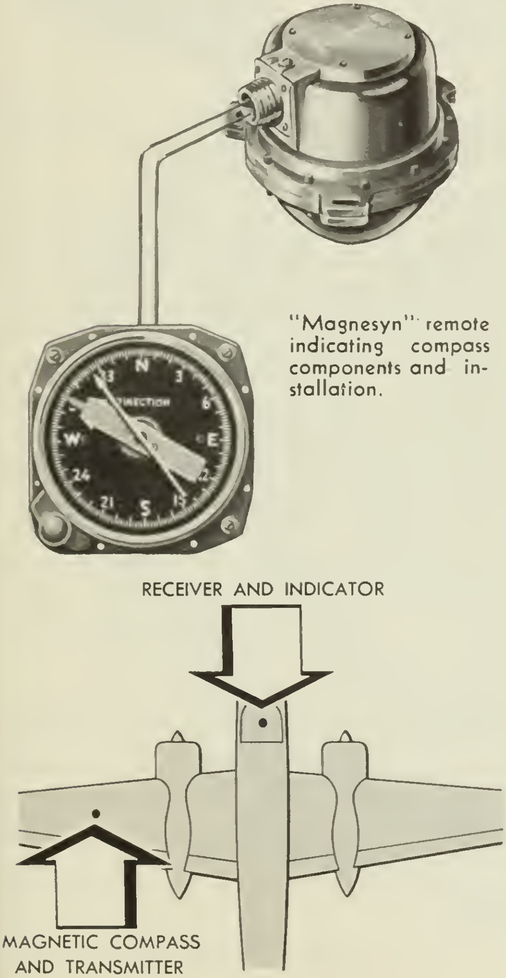
[3] And sometimes called its *course*. The word *course*, however, has other meanings as well.

From AFM 51-38

Gyro stabilized remote indicating "Gyro Flux Gate" compass.



"Magnesyn" remote indicating compass components and installation.

From AFM 51-38

In fact, even before World War II, computers were installed in bombers for automatic solution of the complex and dynamic problems of pinpoint navigation required for precision bombing. The Norden and the Sperry bombsights were nothing more nor less than mechanical computers which, when properly manipulated by the bombardier, guided the aircraft to an exactly computed point in the sky and then released the bombs automatically. This was accomplished by direct electrical connection from the bombsight to the plane's autopilot, and to the bomb-release mechanism. These computers were quite accurate and fairly well suited to the needs of the World War II bombers. But they were useful only when the bombardier could see his target. Though both could be used to help the navigator compute wind conditions at any point during a flight (as long as he could see the ground) they were designed only for precision navigation within sight of the destination—the exact place where a general-purpose navigation device is least needed.

The most recent developments in airborne computers make use of the advances in electronics. The navigator's arithmetic and trigonometric problems can be solved by various kinds of electromechanical analog computers or perhaps by transistor circuits in small digital computers designed along the

Aircraft clock. Even older than the magnetic compass, the usually unheralded clock is one of the most important flight and navigation instruments in an aircraft. Only high precision vibration-free clocks are satisfactory for aviation use.

AFROTC Photo

same principles as UNIVAC and other electronic computers. Several such computers are now in use and under development, including the Air Data System, VORTAC Course Line Computer, VORTAC Pictorial Display, Aircraft Detection and Collision Avoidance, and others.

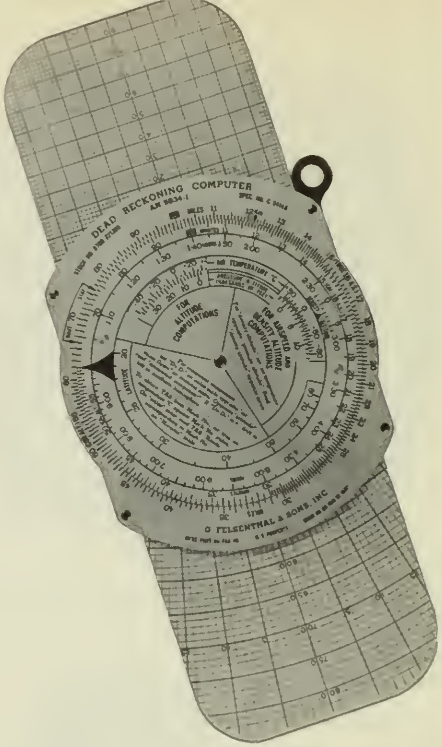
A computer, it must be remembered, is like an adding machine: the answers it grinds out are only as good as the basic data fed into it. This is the principal problem of the self-contained navigational computer. It must be told, for example, what the drift is and the accurate true groundspeed, and this information is sometimes difficult to obtain. Flying over clouds, at night, or in fog or haze, when the ground cannot be seen, the navigator must estimate or rely on radio fixes or other reference to known ground positions.

Airborne Navigational Systems

The ideal of a completely airborne, all-weather navigation device which will display a map with the precise location and heading of the aircraft indicated on it is no longer merely a dream. Even the task of feeding the basic information into the device has been lessened. The new "Doppler" equipment determines drift and groundspeed by radar. And automatic star-sighting is now a feature of some navigation computers. Some instruments, such as the so-called "inertial systems," actually determine the basic information for their computations automatically by reference to gyros and other devices of incredible stability and precision. These have the advantages that they send out no radio or radar signals which could be received by the enemy.

Ground-Based Navigational Systems

Very early in the history of flight, aids were installed on the ground to assist in air navigation. The first such aids were merely light beacons and town names painted on barn roofs.


DEAD RECKONING COMPUTER
AN 5834-1
FOR ALTITUDE COMPUTATIONS
FOR AIRSPEED AND DENSITY ALTITUDE COMPUTATIONS
FELSENTHAL & SONS, INC.

AFROTC Photo

Slide-rule face of an AN–5834–1 dead reckoning computer, a later version of the E6B.

Later, the radio homing receiver was invented—the first radio aid to navigation. This was based on the fact that a loop antenna receives radio signals with minimum intensity when its axis is pointed directly at the radio station to which it is turned. With a loop antenna fixed to the aircraft the pilot could tune in any station of known position, point the plane at it, and receive a very weak signal (or none at all) in his headphones. If his heading shifted so the plane no longer pointed directly at the station, the signal grew louder and the pilot knew he was getting off course. It was a fairly crude system, but it worked (and still works) quite well.

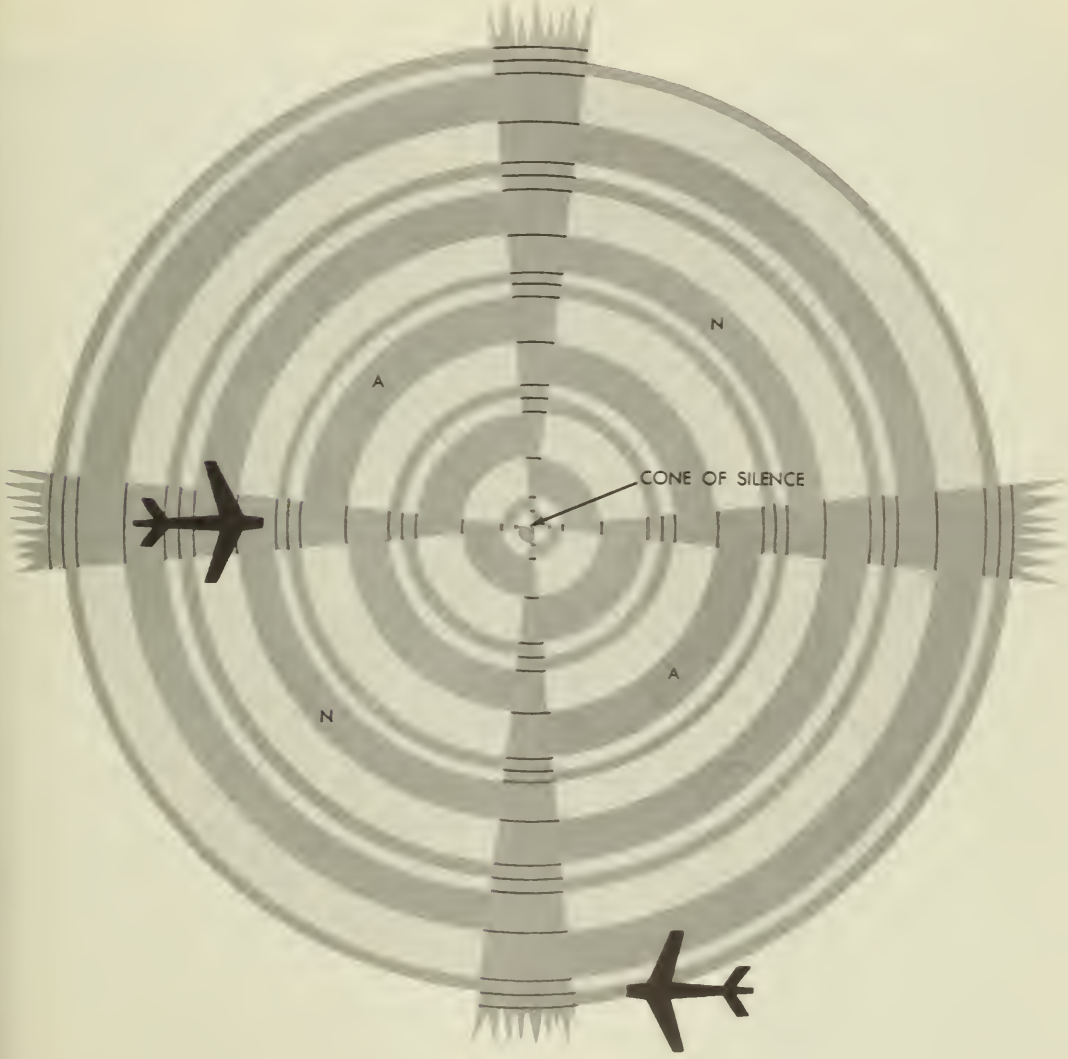
The fixed-loop "homer" or "radio compass" was eventually superseded by the radio direction finder, fondly called the "bird dog." The radio direction finder has a loop antenna which is rotated by a motor. When the set is turned on, the loop automatically rotates so as to point toward the radio station to which it is tuned. The direction in which the loop is pointing is indicated by a compass-like instrument on the instrument panel. The radio direction-finder, though it is subject to interference by static and other phenomena, is still a valuable and widely used device.

Another radio system which came into being fairly early in aviation history was the radio range or "beam."

The direction of transmission of radio waves can be controlled by the use of a loop transmitting antenna. Strong signals will be thrown out from the long sides of such an antenna and almost no signal will be broadcast at right angles to them. So, if two loops are set at right angles to each other, the pattern of broadcasting will look like this. One loop broadcasts a Morse-code *N* (— –) in one pair of opposite directions, and the other loop broadcast *A* (– —) at right angles to it. The broadcasts are spaced so that where the signals overlap, a continuous "hum" is heard by the pilot.

The pilot can fly this "hum" or "beam" directly to the radio range station. If he

Low frequency radio range signal pattern.



gets off the beam, he will hear either A or N, and by identifying which part of the circle he is in, can determine which way to turn to get back on the course.

Since the beam sounds the same whether one is flying toward or from the station, the pilot must be sure to check carefully to be sure he is flying in the right direction.

A complete system of aerial routes defined by beams criss-crosses the entire North American Continent and most other areas of the world. Beam navigation requires the simplest receiving equipment—an ordinary radio—and is therefore extensively used by light-plane pilots.

Recently, a new kind of radio range installation has appeared on the American countryside. The very high frequency omnirange (or VOR) is the radio equivalent of the light beacon, with improvements. VOR stations on the ground transmit signals which are received by a special radio device in the plane. This receiver displays the direction of the station in much the same way as on the radio compass. But VOR signals are not subject to the same distortions that plague the radio compass. It is relatively immune to static and is far more precise.

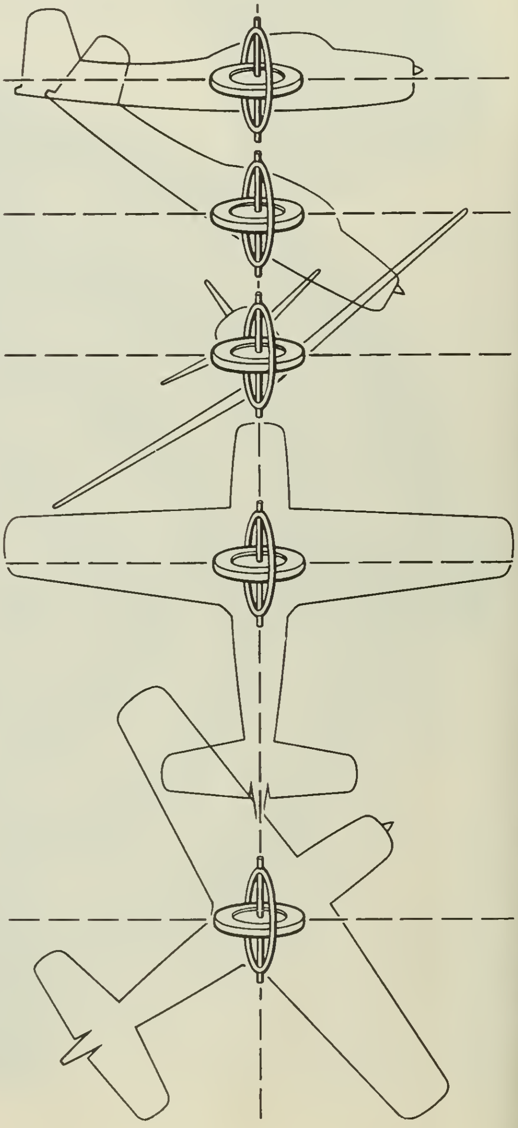
The "homer," the radio compass, the beam, and VOR are all devices for establishing direction alone. They do not tell the pilot how far he is from anywhere. He must still compute that.

During World War II, several ground-based radio systems were invented which provide the navigator with information about his position. The best known of these is Loran (LOng RAnge Navigation). More recent developments are Consol and Navarho, and there are several others.

THE AUTOMATIC PILOT

The automatic pilot consists of a sensing device and a reacting system. By sensing the plane's deviations from straight and level direction and attitude and by applying properly coordinated control pressures, the autopilot actually flies the airplane. Under certain conditions, it can do this better than a human pilot.

The basis of the sensing system of an autopilot is a pair of gyroscopes. A gyroscope in its simplest form is merely a wheel on a shaft. Its mounting is free to rotate in any direction. When the gyro is made to spin very fast (for example, by a blast of air directed at slots or vanes on the wheel) it tends to maintain a fixed attitude regardless of how its mounting may be moved. The attitude of a gyro, therefore, can be used as a reference against which the attitude of the airplane can be compared.



In an autopilot, one gyro is designed to maintain a vertical axis. No matter how the plane may pitch or roll, the gyro remains vertical. The "sensory" system of the autopilot is designed to detect any difference between the gyro's attitude and the plane's attitude. If a difference is detected, this information is sent to electric motors (or hydraulic activators) which work the proper control surfaces to return the plane to straight and level flight.

A second gyro establishes a directional reference. The autopilot refers to this gyro to detect yaw and turn.

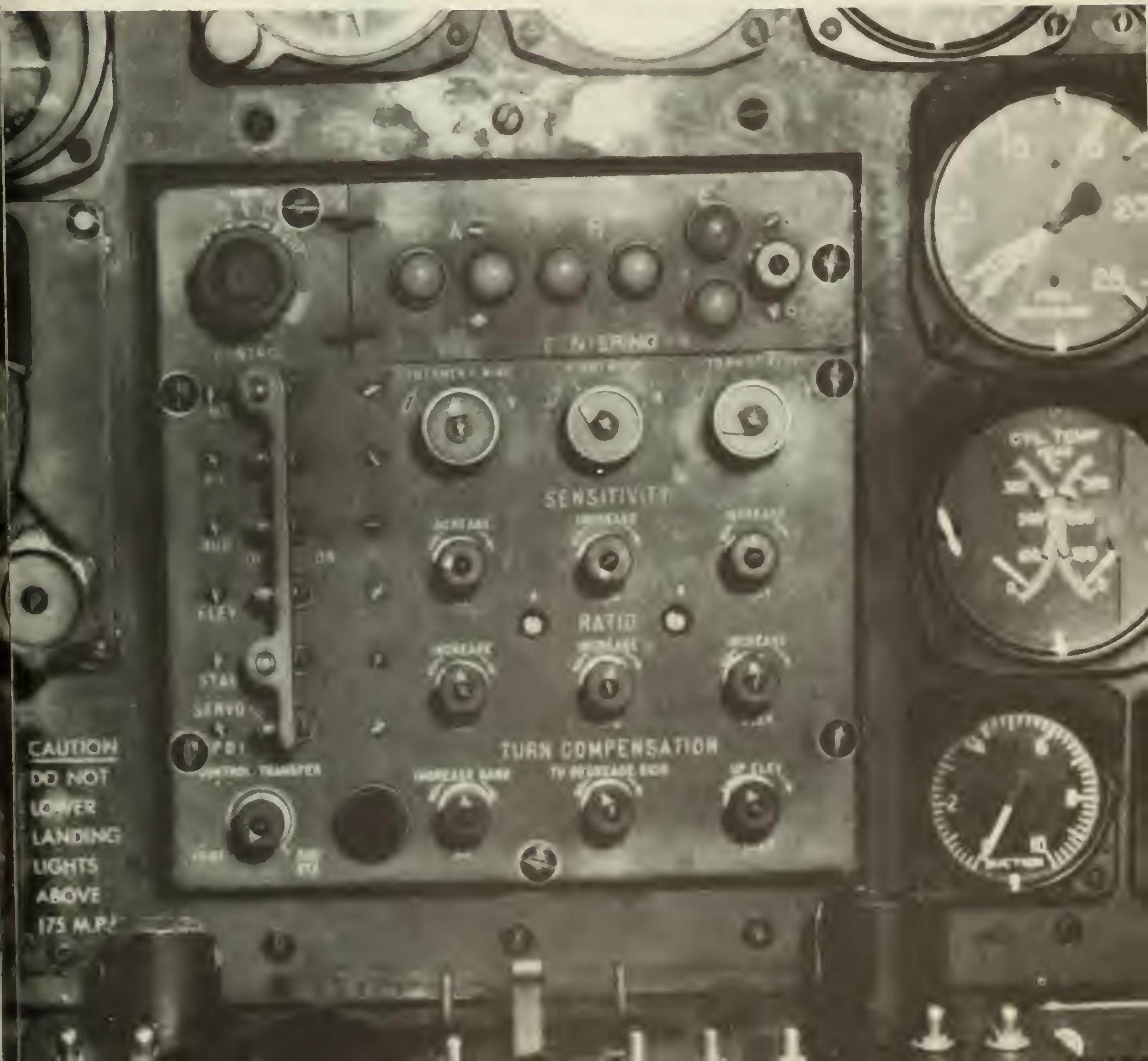
In addition, most autopilots are equipped with a turn control. This is merely a knob which, when turned, causes the autopilot to fly the plane in a coordinated turn.

Autopilots have been designed which can be linked to various navigational devices carried in the plane, or to other devices which receive their "instructions" by radio from the ground.

From these relatively simple principles, scientists have evolved the fabulously precise combination of navigation instruments, autopilots, and "instruction"-receiving radio and radar equipment which are usually referred to as "guidance systems."

Collins autopilot.

AFROTC Photo of Collins' Autopilot



GUIDANCE SYSTEMS

A properly functioning autopilot can be made to control the flight of an aircraft on a constant heading, at a constant altitude, at a constant airspeed. But it does this whether or not the aircraft is going where it ought to go.

A navigation system can be made to determine the true course, true heading, true airspeed and groundspeed, and the location of an aircraft at any moment. It can also be made to supply the heading that should be flown, and the airspeed required, to arrive at a given location at a given time.

Both these operations can be either completely automatic, or subject to control by a human being in the plane or on the ground.

When the control function and the navigation function are combined into a single mechanism, they constitute a *guidance system.* Guidance systems may be installed in manned aircraft to handle certain flight problems too complex or tiring for the human mind and physique. Or they can be used as a combination pilot and navigator for unmanned aircraft or missiles.

Command Guidance Systems

A command guidance system is one in which the flight path of the missile is controlled by some system on the ground. There are six basic operations performed by a command guidance system.

(1) There must be an autopilot capable of maintaining straight and level flight and maneuvering the missile in turns, climbs, and dives.

(2) There is often a computer or central control system which feeds instructions to the autopilot.

(3) There must be a receiver in the missile which can receive information from the ground and give it to the computer.

(4) There must be a transmitter, usually on the ground, to send the information.

The Army's "Redstone" surface-to-surface missile carries a self-contained guidance system. Once the missile is fired, its pre-set instruments control direction, altitude, and length of flight.

U. S. Army Photo

(5) There must be a man or a computer to decide what instructions to send to the missile.

(6) There must be some way of determining where the missile is and where it is heading so the man (or computer) on the ground can decide what instructions to send. In some cases, the ground operator may be able to see the missile at all times. (This may more often be true when the controller is not on the ground, but is riding in a manned aircraft.) But usually, some other method must be used. This could be radar. Or a small transmitter in the missile can be tracked by an automatic receiver on the ground.

The range of operation of such a system is limited by so many factors that many missiles with command guidance systems also carry some form of self-contained guidance system.

Frequently, the command guidance system is used to maneuver a missile from its launcher to a position for some other type of guidance to take over. For example, the missile may be guided by command to a previously calculated position and altitude. After the missile reaches this point, a self-contained guidance system which navigates by the stars can take over. Finally, a "target seeking" system may be used to guide the final dive onto the target.

A distinct disadvantage of command guidance is that the radio signals between the missile and the controller on the ground can be "jammed" by the enemy. If the enemy knows the frequency of these broadcasts, he can broadcast static or false instructions which confuse the missile's computer and flight system. If the enemy could learn enough, he might even be able to take over control of the missile.

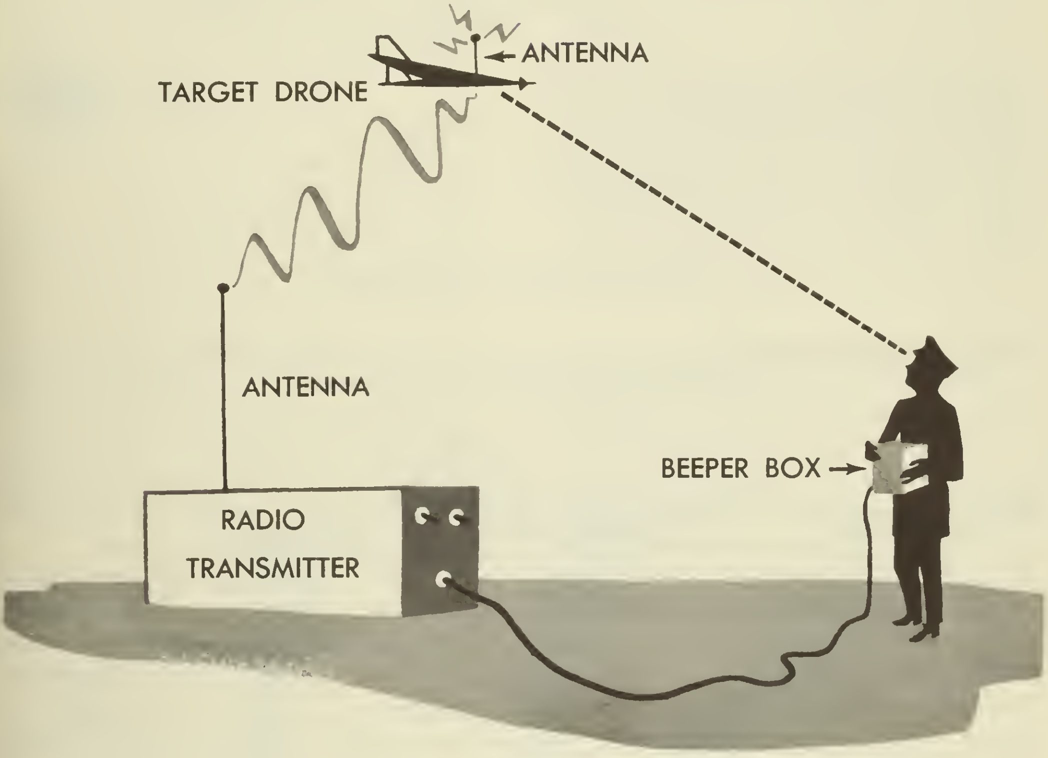
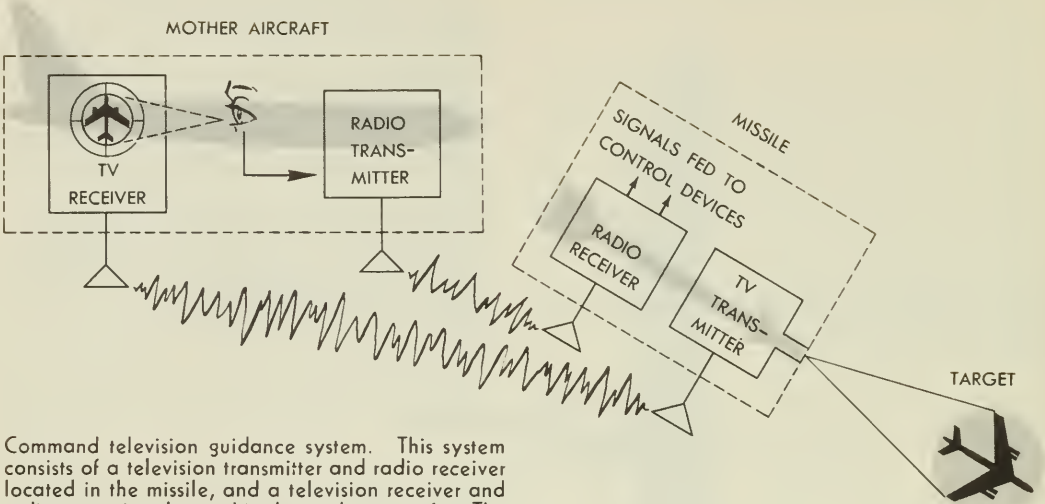


Diagram illustrating the principle of the command guidance system.



Command television guidance system. This system consists of a television transmitter and radio receiver located in the missile, and a television receiver and radio transmitter located in the mother aircraft. The television pictures of the target area provides the controller in the mother aircraft information for issuing radio commands to the missile for closing in on target.

One-radar beam-rider guidance system.

Homing Guidance Systems

A homing system is a device, built into the missile itself, which detects some distinguishing characteristic of the target and heads the missile toward it. The identifying characteristic may be sound, heat, or metal structure (reflected by radar waves sent out from the missile). Or it could be light, or electrical or radio waves emitted by the target. The characteristic chosen for a particular missile to "home in" on will depend on the target for which the missile is designed: factory, city, aircraft, ship, submarine, or perhaps another missile.

Homing systems are of three kinds: Passive, semiactive, or active. A *passive homing system* is one which is designed to select and identify the target by means of natural emanations or radiations from the target itself. Such radiations as heat waves, light waves, and sound waves have been used in passive homing systems.

A *semiactive homing system* is one which selects a target by means of reflected energy from an external source, such as a tracking radar, reflecting from the target. This radar may be ground-based or carried in the launching aircraft. Equipment used in semiactive homing systems is more complex and bulky than that used in passive systems. It provides homing guidance over much greater ranges and with fewer external limitations in its application.

An *active homing system* is one in which the missile carries its own source of energy with which to "illuminate" the target. This could be sound, light, or (usually) radar waves. The missile homes on reflections or echoes of this energy from the target. This system is more complex than either the passive or semiactive types. However, it is well adapted for use in long-range missiles, as it is entirely independent of external sources of target illumination. Power supply requirements are the principal limiting factors in the use of active homing systems. At present this restricts their application to the larger, long-range missiles. As miniaturization of electronic parts is further developed, active homing systems will probably become more generally used.

In all electronic forms of guidance, accuracy decreases as the missile moves away from the source of the controlling information. In fact, highest accuracy it obtained when the *target itself* supplies the controlling information.

Systems using reflected radar waves or infrared heat waves emanating from a target have proven quite satisfactory. At present these systems are quite accurate within their ranges of operation. However, the range of homing systems using infrared, light, or sound from the target is very short, as compared to radar homing systems, which may be employed over considerable distances.

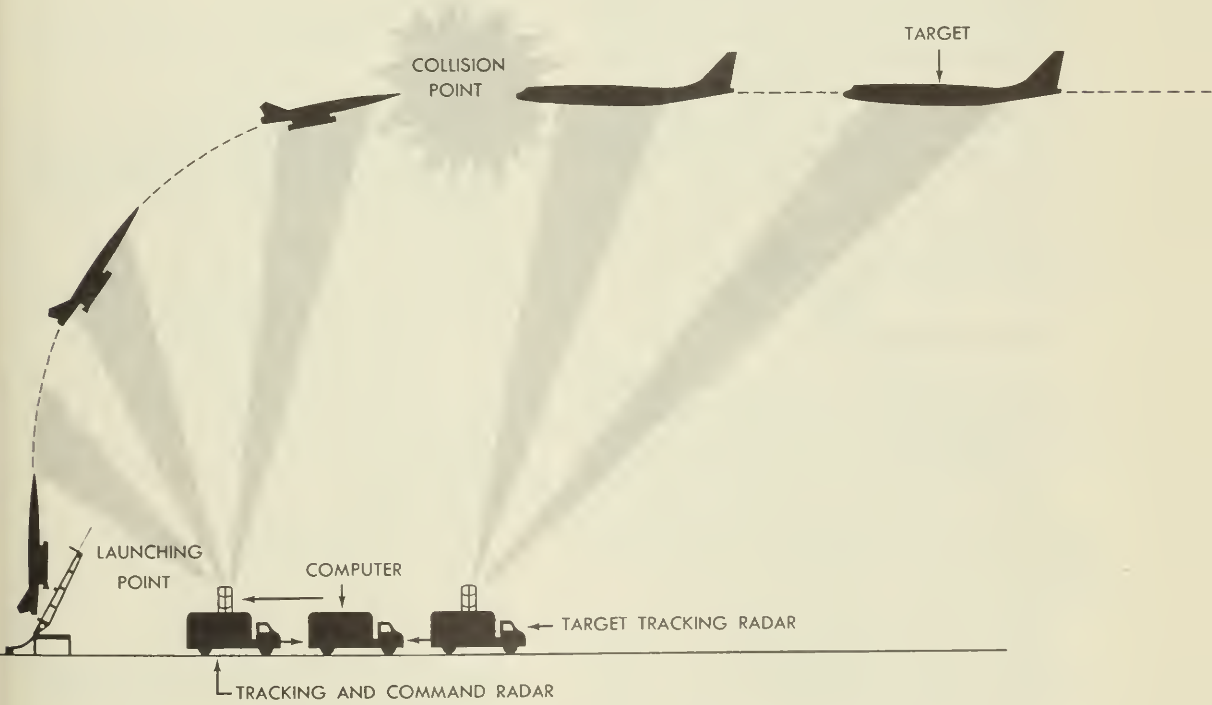
A combination of two or more guidance systems can be more effective than any single system, even though a combination of two or more systems may be more complicated and expensive. In many instances the greater accuracy obtained from combined systems more than justifies their use. The advantages are obvious, for example, of a missile which is guided to the vicinity of its target by celestial navigation and then guided to a direct hit by homing on the heat from a factory.

Applications of Homing Systems

The infrared (radiant heat) homing devices are suitable for use against such targets as mills, factories, bridges, railroad yards, troop concentrations, ships, or any targets which present large temperature differentials with their surroundings. The degree of temperature of the target is not important, but the difference in temperature between the target and its surroundings is the factor which enables the heat seeker to identify the target.

The same principle is employed in light seekers, which are used in missiles designed for use against targets which present a contrast in illumination against their back-

Radar command guidance system uses two radar trackers. A computer controls the radar pulses transmitted to the missile for guidance to target.



Two-radar beam-rider guidance system.

ground light. Again it is the contrast of the light with its background and not its intensity alone which enables the light seeker to home on its target.

Sound seekers are suitable for use against such targets as ships. Such a sound tracker usually homes on the sound of the propellers. Sound seeking is commonly used in torpedoes.

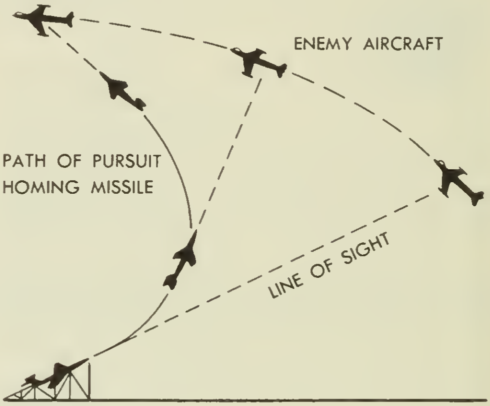
All homing systems are subject to limitations in use. For example, the heat seeker requires a clear, moisture-free atmosphere and could be led astray by countermeasures such as fires purposely set to guide it away from its target. The light seeker may be decoyed away from its objective by bright flares. Also, light-seeking systems require an unobstructed view of the target for accurate homing. Sound seekers, likewise, are subject to diversion unless they are designed to home on sound of a specific frequency, such as that produced by a ship's propellers turning at a constant rate.[5]

In the past, vertical bombing of specific targets with heat-sensitive or light-sensitive homing systems has proved effective when employed under suitable conditions.

Because accurate homing procedure is most necessary during the last part of a missile's flight to its target, much work has been concentrated on this phase, and several methods have been tried. Two methods which have proved satisfactory so far are *pursuit homing* and *lead homing*. Either may use infrared, light or radar homing systems.

Pursuit Homing

Pursuit homing is that type of guidance which requires that a missile travel directly toward the target at all times. A fundamental requirement of any homing system is that the sensing scanner be accurately alined with the longitudinal axis of the missile in which it is installed. Thus, the controls are actuated so that its longitudinal axis is always in line with the target. If the lateral or sideways accelerations required on such a course are computed, they are found to become larger on the last part of the flight path. It is this portion of the flight path which is most critical in obtaining a hit. Since the antiaircraft application is one of the most important of the fire control problems, the use of pursuit homing against fast-moving targets presents certain difficulties. Pursuit homing at the present time appears limited in application.



Lead Homing

A lead-homing missile does not head straight toward its target. The homing system or scanner is able to determine the angular rate of change of its course direction as the missile pursues the target. Of course, this must be in addition to determining the direction of the target. If we can set our missile on a course which keeps its angular rate of change at zero, we have established the condition under which the missile travels directly toward a collision point.

Look at the illustration. Notice that the missile completes the final and critical portion of its trajectory in a straight line. Both vertical and lateral accelerations are small and the most efficient flight path is attained. The problem is roughly the same as shooting a flying duck.

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[5] Fish of certain kinds make a considerable amount of noise which might distract a sound-seeking topedo. This may explain why the Navy has sponsored so much research on porpoise noises and similar projects.

Beam Rider Guidance Systems

Automatic tracking radar for gun aiming was developed to a high level during World War II and has proven effective as an antiaircraft weapon against conventional aircraft. However, such a system is limited by the range of the antiaircraft artillery and would not provide sufficient accuracy or flexibility for effective use against high-speed aircraft or missiles.

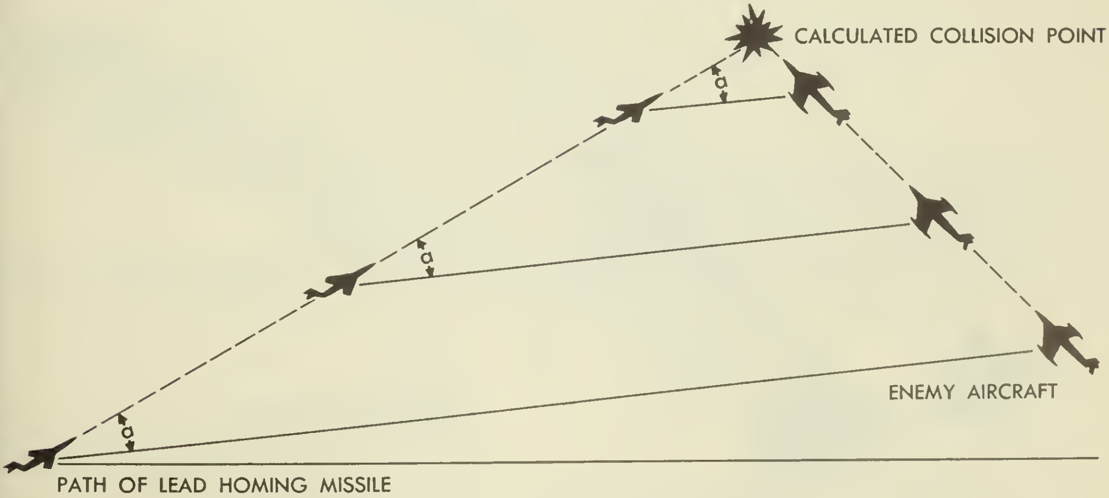
An interceptor missile launched on a fixed trajectory might miss the target as a result of evasive action by the target or pointing errors at launching, even though the tracking radar maintained its "lock" upon the target. If the missile could be made to follow or "ride" a radar beam, the possibility of a hit would be greatly increased.

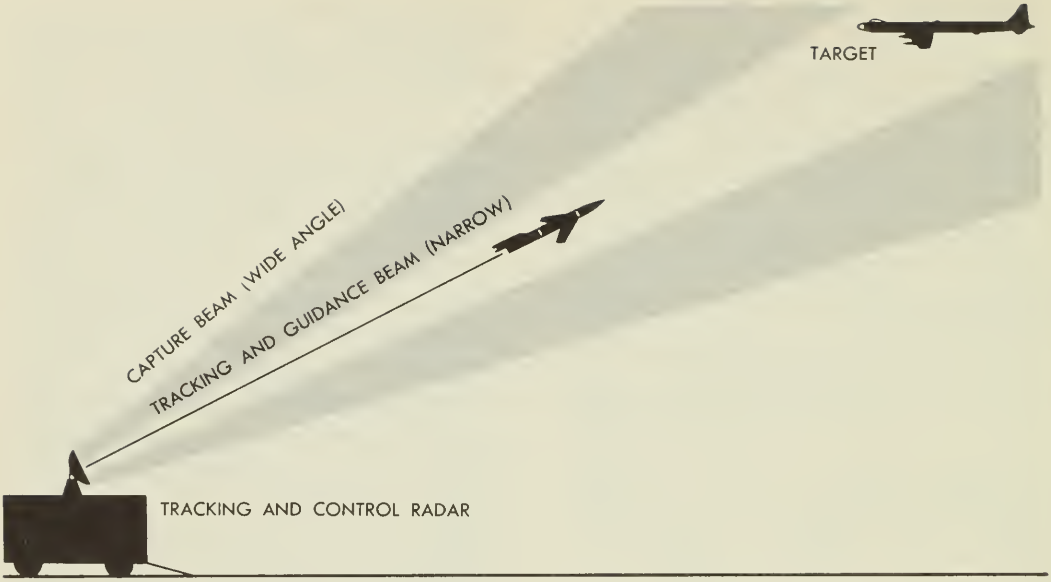
The theory of operation of beam-rider guidance is based mainly upon the principles of the automatic tracking radar systems used for directing antiaircraft artillery. First, consider a missile designed to be guided and controlled by a pulse-modulated radar system. Detection of the target in such a system is accomplished by sweeping a thin beam of pulsed high frequency radio energy in a predetermined pattern through the space to be searched. When the radar beam strikes an object, energy is reflected back to the transmitter. A small portion of this reflected energy is detected by a receiver which is a part of the radar system. Since the transmitting antenna is so designed that the beam it sends out is very narrow, when reflections (echoes) are received back the direction of the target can be determined. The sweeping motion is then stopped and the antenna is moved until the echoes are of maximum strength. The target will then be found upon the axis of the antenna, or in other words, on the center of the beam. Since the beam is pulsed, the elapsed time between the transmission of a pulse and the return of its echo provides the means for determining the distance of the target from the radar transmitter.

Beam-riding missiles are of two types—one-radar and two-radar systems. In a one-radar system, the missile follows a tracking beam to the target.

A more efficient system is the two-radar beam rider. In this case the tracking radar points the control radar as it tracks the target. When the interceptor missile is first launched, it enters a capture beam which assists the missile in acquiring the control beam. The control beam brings the missile and target together to a collision point.

The range of a beam-rider missile unfortunately is limited by the range of the radar system. The beam-rider system af-



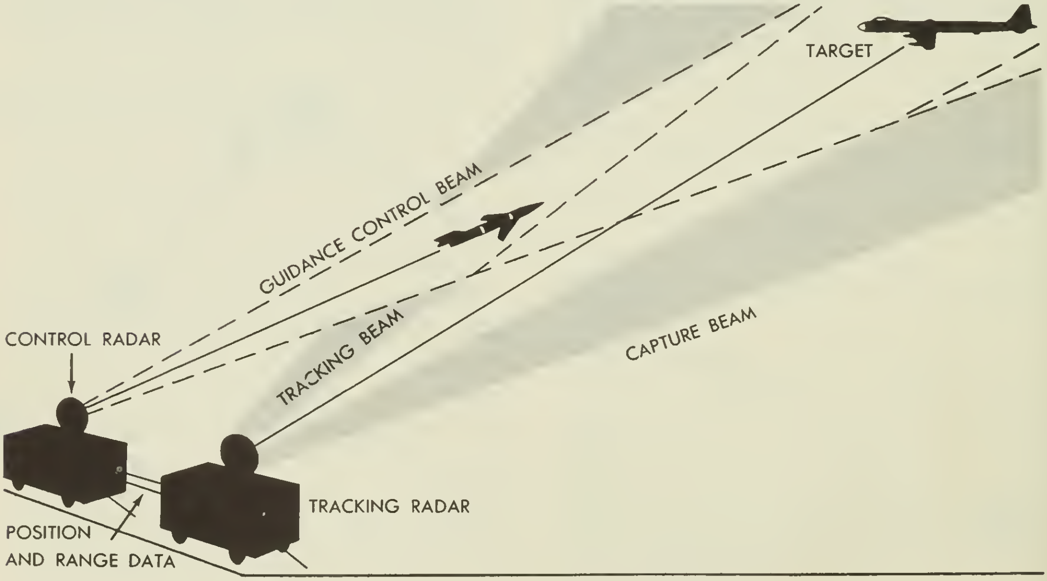

TARGET
CAPTURE BEAM (WIDE ANGLE)
TRACKING AND GUIDANCE BEAM (NARROW)
TRACKING AND CONTROL RADAR

One-Radar Beam-Rider Guidance System.

fords an accurate and practical form of guidance for short-range, high-velocity interceptor missiles and may at some future date be incorporated in larger missiles as a homing system, either by itself or in conjunction with other guidance systems.

Other Systems

Missiles can be designed to use almost any kind of ground-based or self-contained navigation system. They can be guided by gyrocompasses or by celestial navigation. They can be equipped with inertial systems, Doppler systems, or magnetic compass systems. Or they can be made to navigate by radar or loran. In theory, at least, any kind of system which is useful to a human navigator can be built into an automatic guidance system for a missile.

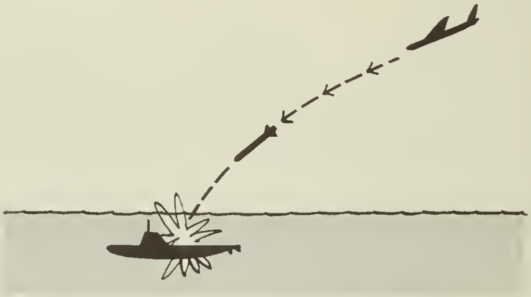


Two-Radar Beam-Rider Guidance System.

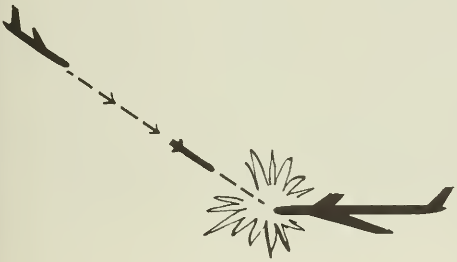
ROLES OF MISSILES

Missiles are coded by role, branch of service, model and other factors. The most common method uses A for air, S for surface, and U for underwater. The service letters are A for Air Force, N for Navy, and G for Army. Thus, ASM–G–3b is an air-to-surface missile used by the Army, third model and second modification. X preceding the code means experimental, Y designates a missile undergoing service tests, and Z means obsolete. Thus, XAAM–A–4c is an experimental air-to-air missile used by the Air Force, fourth model, third modification. Rockets used for research are designated TV for "test vehicle" with a letter indicating the kind of research. Thus, "Lark" CTV–N–9b is a "Lark" missile used for control-system research by the Navy, and is the ninth model, second modification.

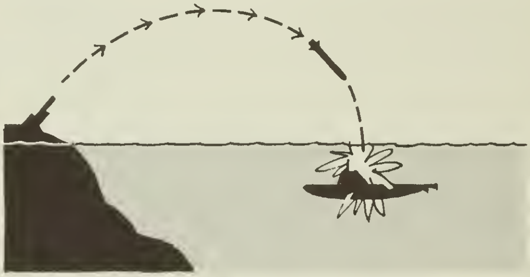
SURFACE-TO-AIR MISSILE



AIR-TO-UNDERWATER MISSILE

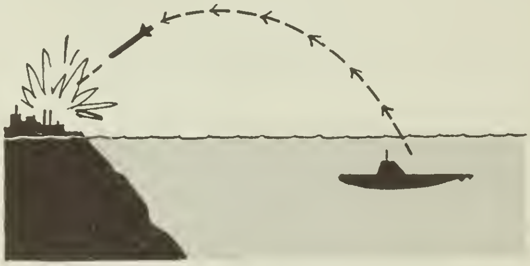


AIR-TO-AIR MISSILE

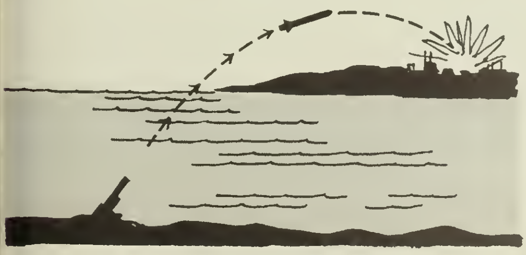


SURFACE-TO-UNDERWATER MISSILE

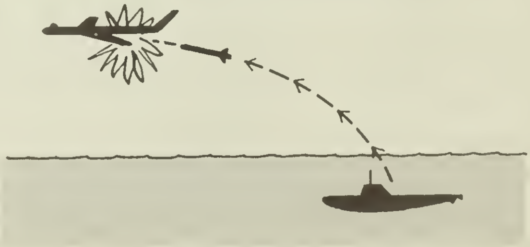
AIR-TO-SURFACE MISSILE



UNDERWATER-TO-SURFACE MISSILE



SURFACE-TO-SURFACE MISSILE



UNDERWATER-TO-AIR MISSILE

PART 2

CHAPTER 10

Propulsion Systems

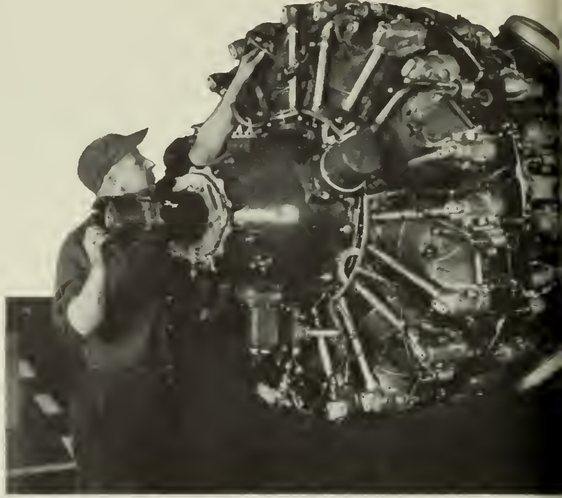
THE TERM *propulsion system* refers to the equipment in an aircraft which produces the thrust force. In a jet or rocket, this is the engine alone. In a propeller-driven aircraft, it is the engine-and-propeller combination.

Rockets and jets are usually rated in terms of their thrust output in pounds of force. Reciprocating piston engines, on the other hand, are customarily rated in horsepower.

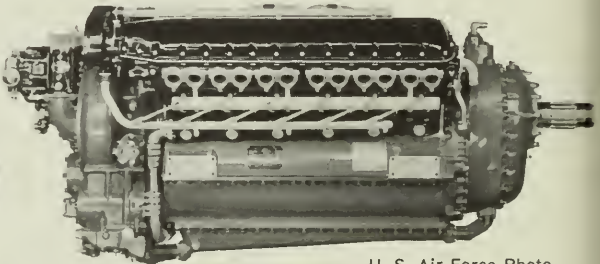
Horsepower is a measure of ability to do a certain amount of work in a specified time. Thrust figures may be converted to equivalent horsepower figures (or *vice versa*) by a simple calculation. One horsepower is equivalent to 375 pounds of thrust moving at 1 mile per hour. Or, 5,000 horsepower is equivalent to 5,000 pounds of thrust moving at 375 mph. Or, to put it yet another way, at half that speed, or 187.5 mph, 5,000 pounds of thrust will do work equal to 2,500 horsepower.

The formula is given here only to provide a convenient way to compare the power output of jets with piston engines in terms familiar to the student. Crew members of jet aircraft seldom concern themselves with such conversions. They are trained to think in terms of thrust rather than horsepower, just as they are trained to think in nautical rather than statute miles, knots and Mach numbers rather than miles per hour, and pounds rather than gallons of fuels.

The first requirement of an aircraft propulsion system is that it provide sufficient thrust for acceleration during maneuvering and takeoff, for overcoming drag in flight, and for climbing. In addition to providing sufficient thrust, it must fulfill the requirements of dependability, reasonable weight, and economy.

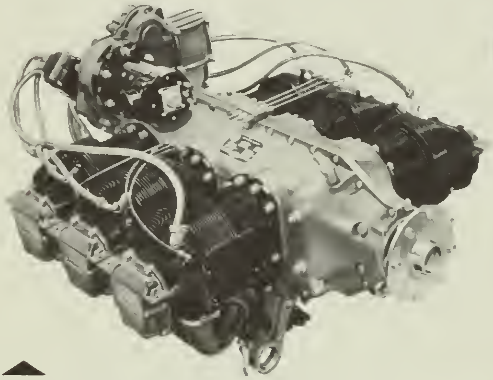


Eighteen-cylinder twin row Wright radial air-cooled engine, the type used to power B–29 bombers.



U. S. Air Force Photo

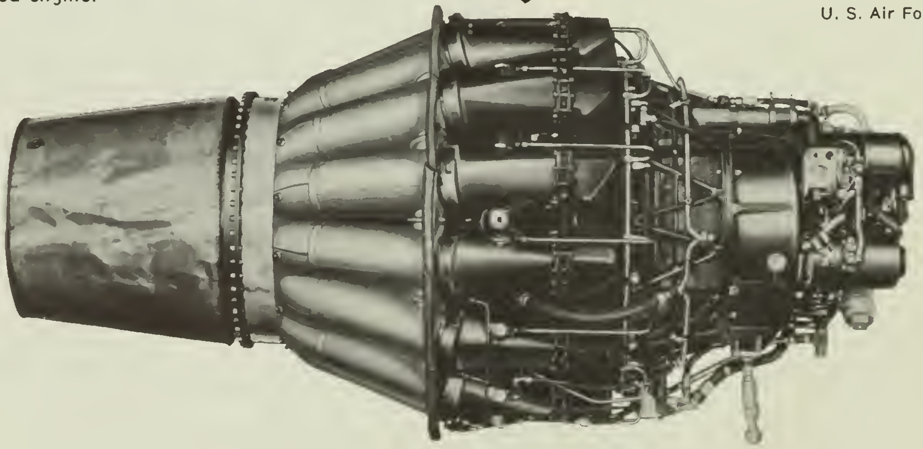
Allison 12-cylinder V-type engine, only liquid-cooled aircraft engine of American design kept in production throughout World War II.

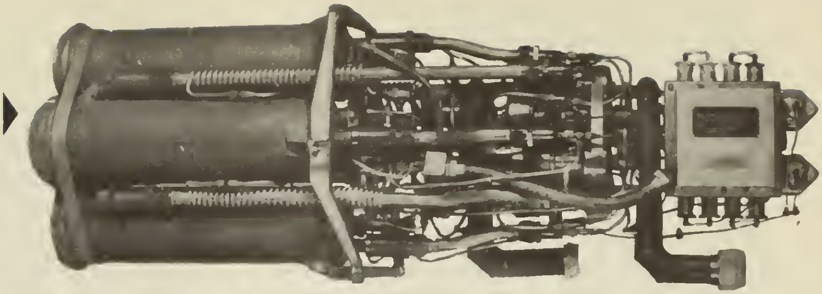


Six-cylinder Continental horizontally-opposed air-cooled engine.

J–33 centrifugal-flow turbojet engine built by Allison and designed by General Electric.

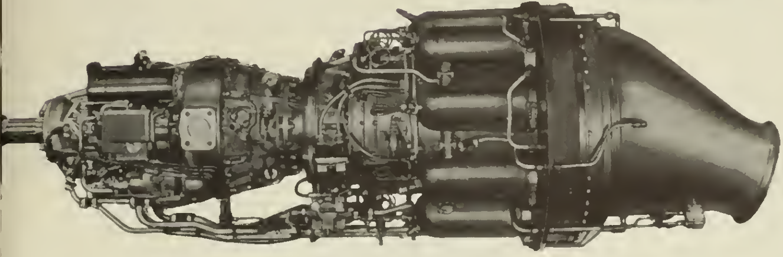
U. S. Air Force Photo





Reaction Motor's 6000-pound-thrust liquid-fuel rocket engine designed to drive the Air Force's Bell X–1.

U. S. Air Force Photo



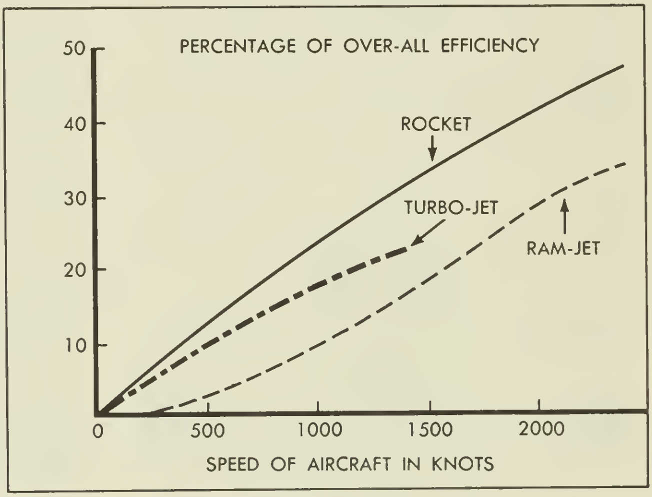
T–31 turboprop engine with axial flow, produced by General Electric.

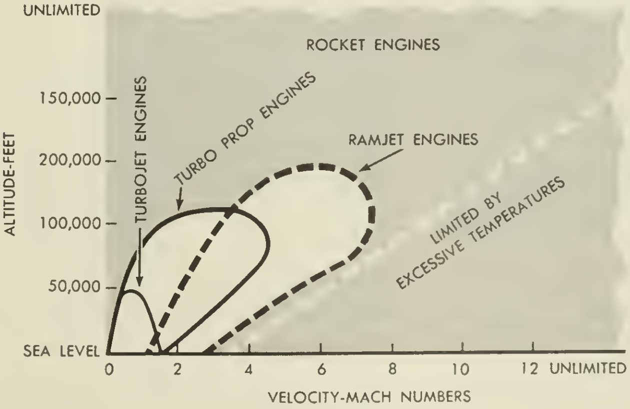
U. S. Air Force Photo

EFFICIENCY OF JET AND ROCKET ENGINES AS RELATED TO SPEED

The efficiency of a rocket engine rises steadily with an increase in speed. The ramjet and turbojet engines also increase in efficiency with speed, but the rise is neither so large nor so steady.

Based on Aircraft Development, ECI publication





Redrawn from Air Force Magazine, March 1958

THE LIMITS OF AIR-BREATHING CRAFT.

Turboprop, turbojet and ramjet engines are efficient only within the ranges of velocity and altitude indicated. Rockets, which are not air-breathers, can function within any ranges except the area of excessive temperatures.

To fulfill its requirements of dependability, it must operate under flight conditions for long periods of time without attention, while delivering an adequate amount of power. A dramatic demonstration of the dependability of the modern aircraft engine was given in 1957 by the three B–52 jet bombers that flew around the world in 45 hours and 19 minutes. The entire distance was flown nonstop and without maintenance. The only attention needed was refueling, which was done in midair.

In the design of an aircraft propulsion system, careful consideration must be given to the total weight—the engine, the propeller if there is one, the engine mountings, and the fuel that the engine must burn. A happy medium must be reached between the weight of the engine and the weight of the fuel. It would obviously be uneconomical to reduce the weight of the engine by 10 pounds if this required an extra hundred pounds of fuel for a flight.

To be economical an aircraft powerplant must be able to burn a fuel that is cheap and plentiful, must be simple to maintain between overhauls, must operate long enough between overhauls to be useful, and must be reasonably inexpensive to manufacture. Naturally the most economical engine for an aircraft is not simply the one that is cheapest to construct. To represent true economy the initial and operating costs of the engine must be compromised with such factors as weight and performance. Automobile engines have been adapted for use in aircraft but have not proved successful. Although the automobile engine is inexpensive to manufacture and readily available, its weight compared to its horsepower output makes it unsuitable for aircraft use, though its appropriateness for use in automobiles is unquestioned.

In the early days of aviation the engines available did not fulfill the requirements we have outlined. They were erratic, undependable, heavy, and very expensive to build. After years of development the aircraft engine may now be said to accomplish what is required of it. With reasonable care and attention it will operate with unfailing regularity, deliver uninterrupted power, and always be ready to perform its functions.

Most aircraft powerplants in present use have certain things in common. Although differing in appearance they all derive their power to operate from principles governed by the same physical laws, and thus are fundamentally the same type of engine.

Some of the most important common denominators of modern aviation engines are:

1. They are all heat engines.
2. They are all internal combustion engines.
3. They all evolve thrust from the principle of reaction.

A heat engine is an engine that operates from the liberation of heat, in this case from the combustion of fuel. This heat is used to expand air or gases to produce work. It is a basic concept of physics that when heat is applied to a gas such as air the gas will expand or its pressure will increase, or both. The increase in pressure can be used directly to produce work, as in a piston and cylinder. When the piston is forced to move by the pressure, it can be made to perform useful work, such as turning the propeller. In another type of heat engine, the expansion of heated gases is used to form jets of gas which produce thrust.

When we say that an aircraft powerplant is an "internal-combustion engine," we simply mean that the fuel is burned within the engine itself to produce the heat necessary for it to function. An example of a heat engine that is not an internal-combustion engine is the common steam engine. In this type of engine the fuel is burned to heat water and produce high-pressure steam. This heated steam flows through pipes, sometimes for a great distance, to the engine, transmitting the pressure force to the engine. The pressure of the live steam furnishes the force to operate the engine. In all present aircraft engines the fuel is transmitted to the engine and is burned within the confines of the engine itself.

FUELS

The commonest forms of engine fuel in use today are the hydrocarbons derived from petroleum. The best known are gasoline, kerosene, and diesel fuel. These fuels have certain desirable characteristics which make them practical energy sources for modern engines.

1. They are volatile. That is, they evaporate quickly under suitable conditions and can be easily mixed with air to form a combustible mixture.
2. They ignite at relatively low temperatures. If the flash point (the lowest temperature at which a fuel will ignite spontaneously in air) is too high, the engine will be difficult to start.
3. They have a very low freezing point, so there is no serious danger of their freezing in the tanks at high altitudes or during storage in arctic conditions.
4. They have a relatively high heat content. That is, they "burn hot," liberating a great amount of energy.
5. They are easily handled under fairly simple safety precautions. They do not require elaborate or complex safety procedures during storage or transportation.
6. They are relatively stable and do not deteriorate or become hazardous when stored for long periods of time at normal temperatures.
7. They are readily available at reasonable cost.

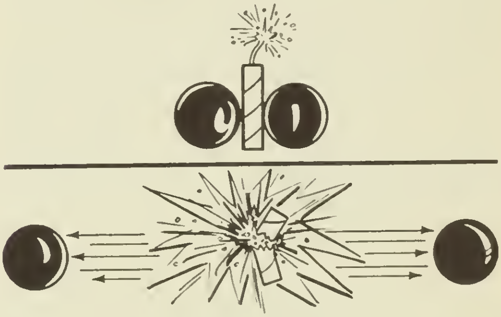
Within each type of hydrocarbon fuel, there are many grades. For proper operation, each must be used with the engine for which it was designed. When an engine is designed, the type and grade of fuel chosen has considerable bearing on details of construction and will be the most important factor determining the engine's ease of starting and restarting, operating temperature, and maximum power output.

The subject of fuels is not complete without mentioning the oxygen necessary to burn them. Correctly speaking, a fuel exists only when a source of energy, such as gasoline, is mixed with oxygen. The oxygen is normally supplied from the atmosphere. Gasoline by itself, for example, will not burn in an engine, but must be mixed with oxygen to form a combustible mixture. By common usage, however, substances such as gasoline have come to be called fuels. Those engines which use the atmosphere as the source of oxygen are called atmosphere-dependent engines. All the reciprocating engines and the jets are included in this category.

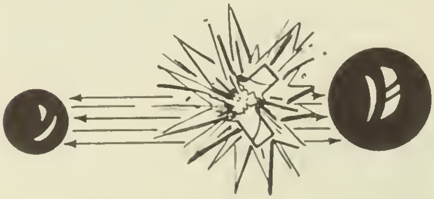
At present, the only atmosphere-independent power plant is the rocket, which carries its own oxygen supply.

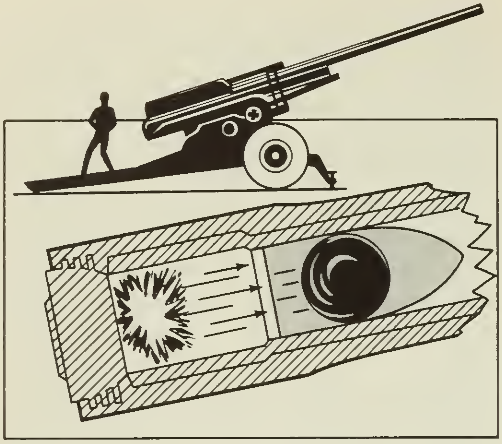
THE LAW OF ACTION AND REACTION

If we exploded a firecracker between two identical steel balls, we would expect the balls to roll away at the same speed.



If one were heavier than the other, we would expect it to roll away more slowly than the light ball. We do not explain this to ourselves by claiming that less force was exerted on the heavy ball, but by pointing out that a certain amount of force can either move a large mass just a little, or a smaller



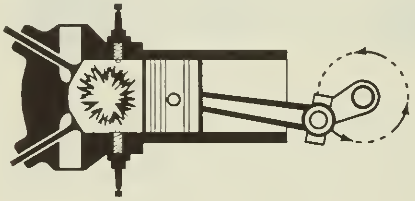


mass quite a bit. We know, for example, that replacing the heavy ball with a cannon does not change the laws of physics. When the explosion occurs, the cannon will travel in one direction and the ball in the other. The cannon will travel only a few inches, while the ball may travel several hundred yards. But this is not because a greater force was applied to the ball than to the cannon; the two forces are equal. It is solely because the cannon is heavier.

The force applied to the ball is called the *action* force. The force applied to the cannon is called the *reaction* force. The physical law states that, *for every action there is a reaction, and that these two forces are equal and opposite.*

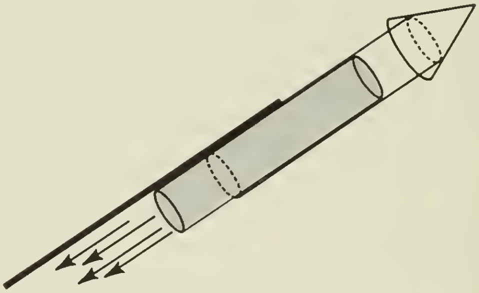
There is no magic performed by choosing to call the force applied to the ball the action force. If we were interested in moving the cannon, and decided to do this by firing it, we might reverse our terms. This would leave the laws of physics quite unchanged.

If we now replace the cannon ball with a piston, and the cannon with a cylinder, and if the explosion is caused by igniting a mixture of gasoline and air instead of gunpowder, we can create an engine. Nor does this alter the law of action and reaction. The cylinder ("cannon") no longer moves from its position, but the force applied to it is no less. The cylinder is simply fastened down so tightly that the reactive force cannot move it. Leave the cylinder head loose and the reactive force will become immediately and violently apparent.



THE ROCKET

A rocket is, in a manner of speaking, an engine cylinder. In this case, the reaction mass is not a steel piston, but is the gas produced by the explosion of the fuel. Gas is, of course, a substance. The kind of mass it has is not essentially different from the kind of mass a steel piston has. The only difference is that, given a piston of gas and a piston of steel the same size, the gas has less mass.



In either case, the explosion will shove the gas "piston" in one direction (action) and the cylinder in the other (reaction).

Now, rather than have one sudden explosion, we so arrange things that the explosion is extended over a long period. We can do this by continually adding more explosive. Or if we prefer to use a solid fuel, we can arrange it so that it burns at a particular

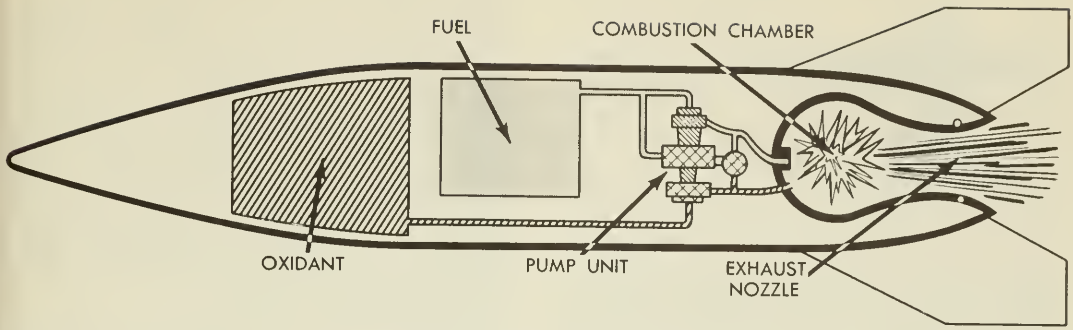


Diagram of liquid-fuel rocket.

rate ("explodes slowly"). This will provide a continuous thrust force to drive the rocket forward.

Rocket Fuel Systems

One way of describing the efficiency of a rocket fuel system is to express it in terms of *specific impulse.* This is the constant thrust (measured in pounds of force) that can be produced by burning 1 pound of fuel per second. In more technical terms, specific impulse is pound-seconds of thrust obtainable by burning a pound of fuel.

The thrust (the *reactive* force) can only be increased by increasing the *active* force. This can be done by either of two methods: (1) by increasing the mass of the gas shoved backward, or (2) by increasing the velocity at which the mass is shoved. Or we could do both. It turns out that the easiest thing to do is to shove the gas out at the maximum possible velocity.

So far, the most practical method of obtaining the high ejection velocities required is by using a gas that expands very rapidly, and by requiring it to expand through a nozzle. When the gas expands, it has no space to expand into except straight out the back of the rocket. So it expands in that direction, at tremendous velocity, and is propelled backward by the force derived from its own expansion.

The burning process in a rocket is like any other burning process in that the fuel must be mixed with oxygen before it will burn. In all other present-day aircraft engines, this oxygen is obtained from the atmosphere. The rocket, however, carries its own supply of oxygen.

The fuel system of a rocket engine may be one of two types: (1) those burning solid propellants, and (2) those burning liquid propellants.

The solid-fuel rocket is the older and has been used much more extensively than the liquid-fuel system. The solid fuel is stored right in the combustion chamber, and the rate of burning is controlled by adjusting the surface area exposed. Oxygen is supplied directly from the chemicals being burned. Burning pressure is usually 1,000 to 2,000 pounds per square inch, the exact amount being determined by the characteristics of the propellant.

The solid propellants can be divided into three groups according to their burning time. Fuel with a short burning time is used to give a relatively high thrust for a short period of time. It is generally used when high accuracy is required. In a rocket motor, the velocity and direction of the gas are seldom uniform over the nozzle cross section, and there are often mechanical misalignments. Therefore, if high accuracy is required, the rocket must be guided during the time of burning, as is the case with the bazooka.

In this weapon a high acceleration is required for a very short time. Double-based powders of the nitroglycerine-gun cotton

type are used. The specific impulse for such systems would be around 250 pounds of force, corresponding to a jet velocity of about 8,000 feet per second. The accelerations are about the same as those for the projectiles of regular guns. Therefore, rockets using solid propellants with a short burning time must be built strong enough to withstand the high acceleration forces.

The intermediate type of propellant, which has a burning time of 3 to 5 seconds, is used when the rocket is less rugged and less accuracy is required, or when guidance can be applied over a longer period. A typical use is for the barrage rocket. Double-based powders have been used for this purpose, but difficulties have been experienced in obtaining slow combustion rates. Therefore composite propellant systems, such as mixtures of sodium picrate and potassium or ammonium nitrate, are used instead. These composite propellants have a specific impulse of about 175.

Slow-burning propellants, which have a combustion time of 30 to 60 seconds, are used in the rocket-assisted-takeoff of airplanes. A mixture of asphalt and potassium chlorate, called Galcit, is one kind. It gives a specific impulse of around 170. Since this mixture tends to be brittle when cool and soft when hot, it cracks and runs. As a result, the area exposed for burning increases, and failure ultimately results. It must therefore be stored and handled with care.

U. S. Air Force Photo

An Air Force "Snark" intercontinental-range missile blasting off with aid of two booster rockets which jettison after burning out. Missile is driven by a Pratt and Whitney J–57 turbojet engine.

The solid propellants are almost always carried within the combustion chamber. Thus, during combustion, the whole area where the propellant is stored is under pressure, and heavy construction is necessary. The weight is not particularly serious in small motors, but it becomes a major problem in the design of large rocket engines. The solid propellants also suffer from the disadvantage that the burning rate depends on the shape of the material, the initial temperature, and the pressure. Pressures of 1,000 to 2,000 pounds, which are usually necessary for obtaining satisfactory burning rates, require strong, heavy cases. The composite propellant and Galcit also produce large volumes of smoke.

The one real advantage of solid propellants is their simplicity. No pumps, valves, or regulators are required. Most solid propellants can be stored easily over long periods of time and are thus ready for immediate use.

The liquid fuel system offers better control. The combustion rate can be regulated by the rate at which the liquid is introduced into the combustion chamber. But some method must be provided for forcing the liquid into the chamber in proper amounts. In the small, short-range rockets, the liquids are usually introduced into the combustion chamber by pressure. In very large rockets it is more practical to pump them into the combustion chamber.

Liquid-fuel systems are either monofuel or bifuel. In monofuel systems a single liquid supplies both the fuel and oxidizing material. In the bifuel systems two liquids are used. One is the fuel, and the other is the oxidizer. Naturally the bifuel systems are complicated, but they have the advantage that, generally, neither liquid by itself is explosive.

Ratio of Initial Weight to Final Weight

Specific impulse is not the only criterion of the performance of a rocket. The ratio of the initial weight of the rocket to its final weight is also important. It is desirable to have this ratio large or, in other words, most of the weight should be devoted to fuel and not to the engine.

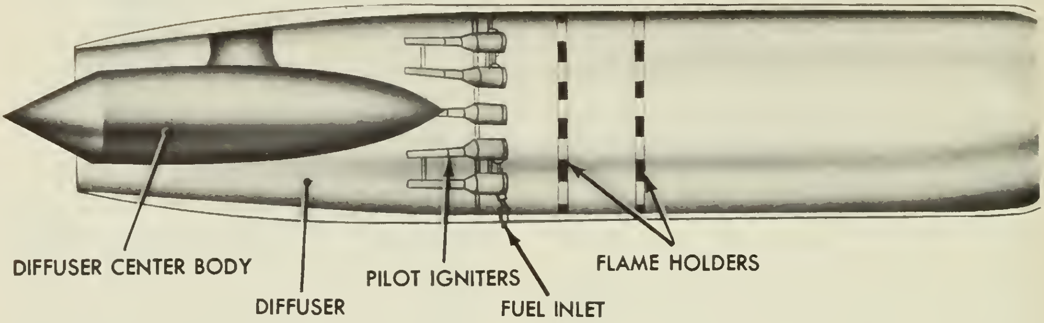
When a solid propellant is used, the storage chamber is a part of the combustion chamber, and no pumping or control system is needed, but the storage system must be heavy enough to withstand the high operating pressure of the rocket engine. It is for this reason that solid propellants are limited to relatively short ranges, and it is doubtful whether a system can be designed for a solid rocket that has a weight ratio higher than 3 to 4.

When liquid propellants are used, they are not ordinarily stored in the combustion chamber but are forced into it at a controlled rate. If the liquid is stored under pressure, the tanks must be of heavy construction, and the rocket has the same weight handicap as one burning a solid propellant. If the liquid is stored at low pressure, the storage tanks can be lightweight and the ratio of initial weight to final weight is more favorable, provided the rocket is large. In large rockets, ratios as high as ten should be possible. Such a high ratio would make a tremendous difference in the range that could be obtained. However, the pumps and other equipment needed for low-pressure fuel-storage systems weigh almost as much for a small rocket as for a large one. In small rockets, their weight nearly offsets the advantages gained by using the lightweight storage tanks. So low-pressure systems are most practical in large rockets.

THE RAMJET ENGINE

A ramjet engine might loosely be called a "rocket" which does not carry its own source of oxygen. It acquires the necessary oxygen from the atmosphere. The air is, in fact, rammed into the front of the engine as the engine moves forward. For this reason, a ramjet engine cannot be operated at all until some other force gets it moving through the air at a considerable velocity. Aircraft with ramjet engines must therefore have another engine as well, which can be used to get the aircraft up to a velocity sufficient to start the ramjet.

Diagram of a supersonic ramjet engine.



There are four "stages" in the functioning of a ramjet engine: (1) *Intake,* which is accomplished by moving the engine forward through the atmosphere; (2) *compression,* which is partially performed by the diffuser cone as the air enters; (3) *combustion,* in which fuel is sprayed into the air passing through the combustion chamber and ignited (first by a spark plug, then by the continuous combustion); and (4) *exhaust,* which takes place at high velocity through a nozzle at the back.

The ramjet operates best at (and is nearly always designed for) supersonic speeds. Generally, it does not even start below about 250 knots. The second engine, which accelerates it to its starting speed, may be a turbojet or a rocket.

The ramjet produces tremendous thrust for its weight and has an extremely high rate of fuel consumption. But it is a peculiar characteristic of the ramjet that, the faster it goes, the more thrust it produces at the same rate of fuel consumption. Therefore, at supersonic speeds, the ramjet approaches the piston engine in fuel economy.

Because of its capability for high-speed propulsion, the ramjet is often used in missiles. It can also be used as an auxiliary source of power to give short bursts of speed to more conventional types of aircraft, such as a turbojet fighter.

THE TURBOJET ENGINE

The turbojet engine has made a tremendous impact on the development of aviation. It is relatively light in weight for its thrust and, though its fuel-consumption rate is high, its performance characteristics more than make up for this disadvantage.

Like the rocket and the ramjet, the turbojet engine can be employed as the propulsion system for a manned aircraft or for a large missile. At the present time, the turbojet appears to be the most practical engine for high-speed flight, and it is rapidly being adapted to commercial transport applications and even to executive-type private aircraft.

All the operational supersonic aircraft now in use by the United States Air Force are powered by turbojet engines. With rare exceptions, this is also true of all other air forces in the world today.

The U. S. Air Force's recent adoption of a new turbojet-powered primary trainer marks the beginning of a new era of aviation in which a military pilot may complete his entire training and take an operational assignment without ever having flown a propellor-driven aircraft.

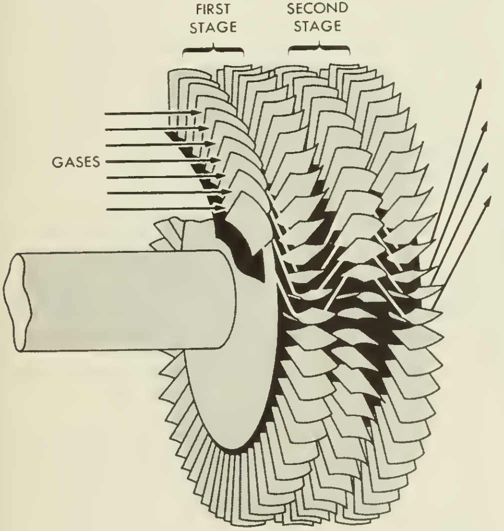
A turbojet engine differs from the ramjet mainly in that it contains a device for "ramming" the air into the combustion chamber. This device is called the compressor.

In starting, the compressor is rotated by an electric motor, but after the engine is operating, the compressor is rotated by a turbine which is set farther back in the engine.

The turbine acquires its rotation from the blast of hot gases as they pass back toward the exhaust nozzle.

Here, as in the ramjet, there are four "stages" of operation. The importance of this engine in modern aviation makes it worthwhile to examine these stages in some detail.

The air enters the engine at the front. In part, the intake air is rammed in by the movement of the engine through the atmosphere. In part, it moves in because of the low pressure caused by rotation of the compressor.



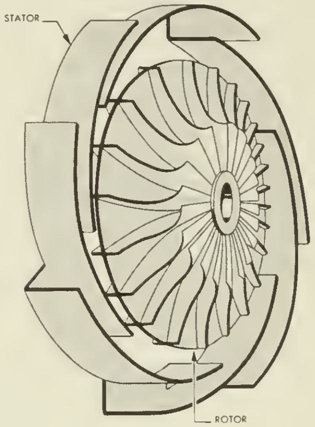
A multiple-stage turbine consists of a rotor and stator for each stage. The rotors are spun by the hot gases coming directly from the combustion chambers. The stator blades direct the flow. The metal of the turbine must withstand extremely high temperatures during operation. During starting and stopping, the temperature may change several hundred degrees almost instantaneously.

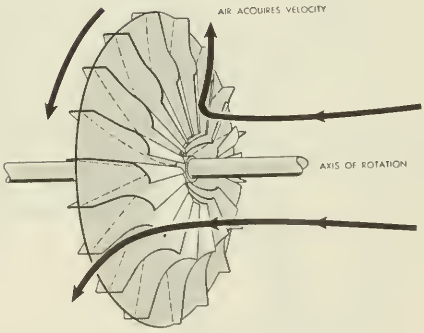
The shaft which connects the turbine with the compressor must be capable of handling tremendous stress. In one typical engine, this shaft must transmit as much as 10,000 horsepower from the turbine to the compressor.

The Compressor

As the incoming air enters the compressor, its velocity is reduced and its pressure is raised. There are two principal ways of doing this: the centrifugal compressor and the axial-flow compressor.

The centrifugal compressor is the simpler. It is composed of a rotor, a stator, and a casing. The rotor is mounted within the stator, and the complete assembly is in-



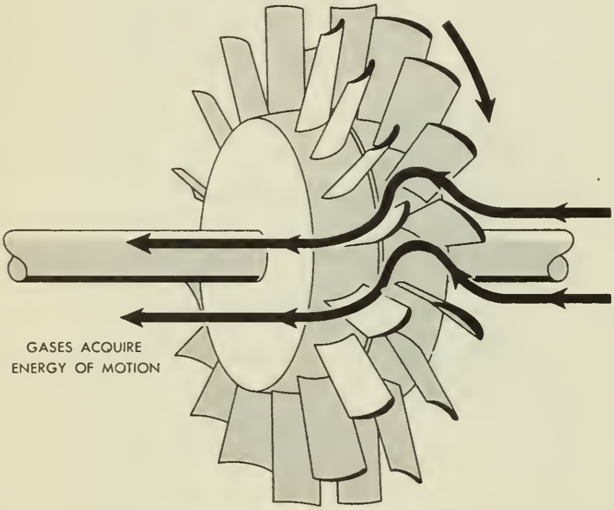


The centrifugal compressor consists of a rotor and a stator which are inclosed in a casing. As the rotor revolves, air is drawn in near its center, whirled around by the rotor blades and ejected by centrifugal force at high velocity against the stator blades. There its velocity is converted into pressure energy as the air passes toward the combustion chambers.

closed in the casing. The casing has an opening near the center of the rotor for the entering air, and channels at the rim of the rotor to direct the exit air to the combustion chambers.

The rotor is made up of a series of flat blades as shown in the illustration. As these blades revolve about the axis, air enters the rotor at the center. Centrifugal action causes the air between the blades to move outward from the axis of rotation toward the rim of the rotor, where it is ejected with considerable velocity. The rotor may be of either the single- or double-entry type. In the double-entry type, air enters the center of the rotor from both front and back.

The stator of the centrifugal compressor consists of diffuser vanes or blades which curl outward from the central axis. The stator does not rotate. The energy which the mass of air acquires as velocity in the rotor is efficiently converted into pressure by the stator. The air is allowed to expand as it moves into the several divergent passages formed by the stator's diffuser vanes. When the air expands, it loses its velocity, which is converted into pressure, since the total energy must remain the same. The compressed air is channeled to the combustion chambers.



A single stage of an axial-flow compressor contains one set of rotating and one set of stationary blades. As the rotor turns, air entering the engine is compressed by the fan-like action of the rotor blades and passed to the stator whose stationary blades straighten out the flow and direct the air on to another set of rotor blades or into the combustion chamber.

The centrifugal compressor just described is now almost entirely replaced by the axial-flow compressor, which can give a greater amount of compression with a smaller cross-sectional area.

The axial-flow compressor operates much as an aircraft propeller does. The rotor is a many-bladed propeller mounted on a central shaft. As this rotor turns, the blades throw the air backward and toward the rim. This motion creates pressure in a manner similar to the ram effect. A set of stationary blades is mounted after each rotor. These stationary blades serve to straighten out the flow and to direct the air into the next rotor. A set of rotating and stationary blades together is referred to as a *stage*. Axial-flow compressors can be made up of any number of stages, depending on the pressure rise desired.

The Combustion Chambers

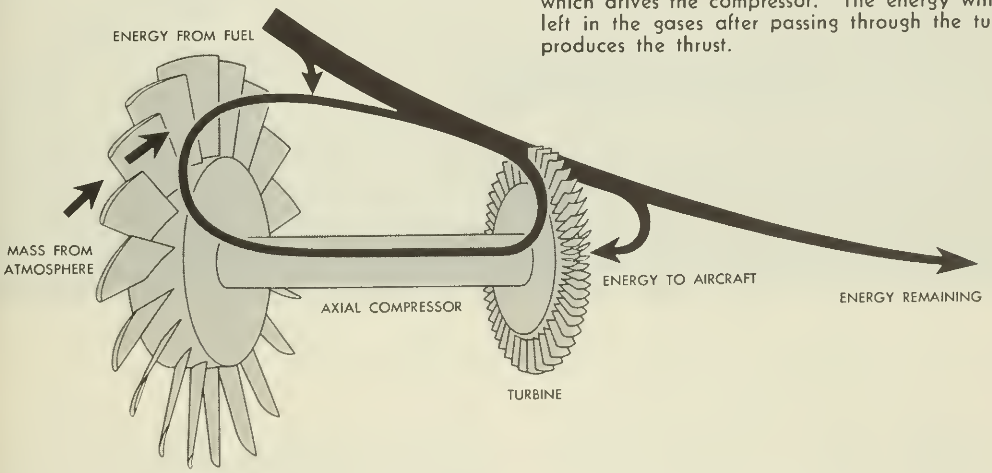
From the compressor, the air moves back toward the combustion chambers. At this point, in a typical engine, it is divided and most of it flows around the outside of the combustion chamber to cool it. It then enters the combustion chambers through the holes in the inner shell so the proper ratio of fuel to air can be maintained for efficient burning.

The remainder of the air goes directly into the combustion chamber for mixing with the fuel. Here, the fuel is injected in a steady flow and at high pressure—about 700 pounds per square inch—and combustion is continuous. The energy released raises the temperature in the combustion chamber to about 3,250° F. Since the end of the chamber is open, the expanding gas rushes out toward the turbine.

The Turbine

In the turbojet engine with a single-stage turbine, the flow of gas from the combustion chambers first strikes against a set of stationary blades in what is called the stator or nozzle diaphragm. Like the stator blades in the compressor, the turbine stator blades are fixed in position and do not move. Their purpose is to deflect the rushing gas slightly to make it strike the blades of the rotor at the most efficient angle. They also constrict the gas flow and therefore accelerate it to high velocity.

The turbine rotor is essentially a windmill mounted on the same shaft as the compressor. The rush of gas from the stator causes the turbine rotor to revolve at about 7,000 to 12,000 revolutions per minute, the exact number depending on details of design.



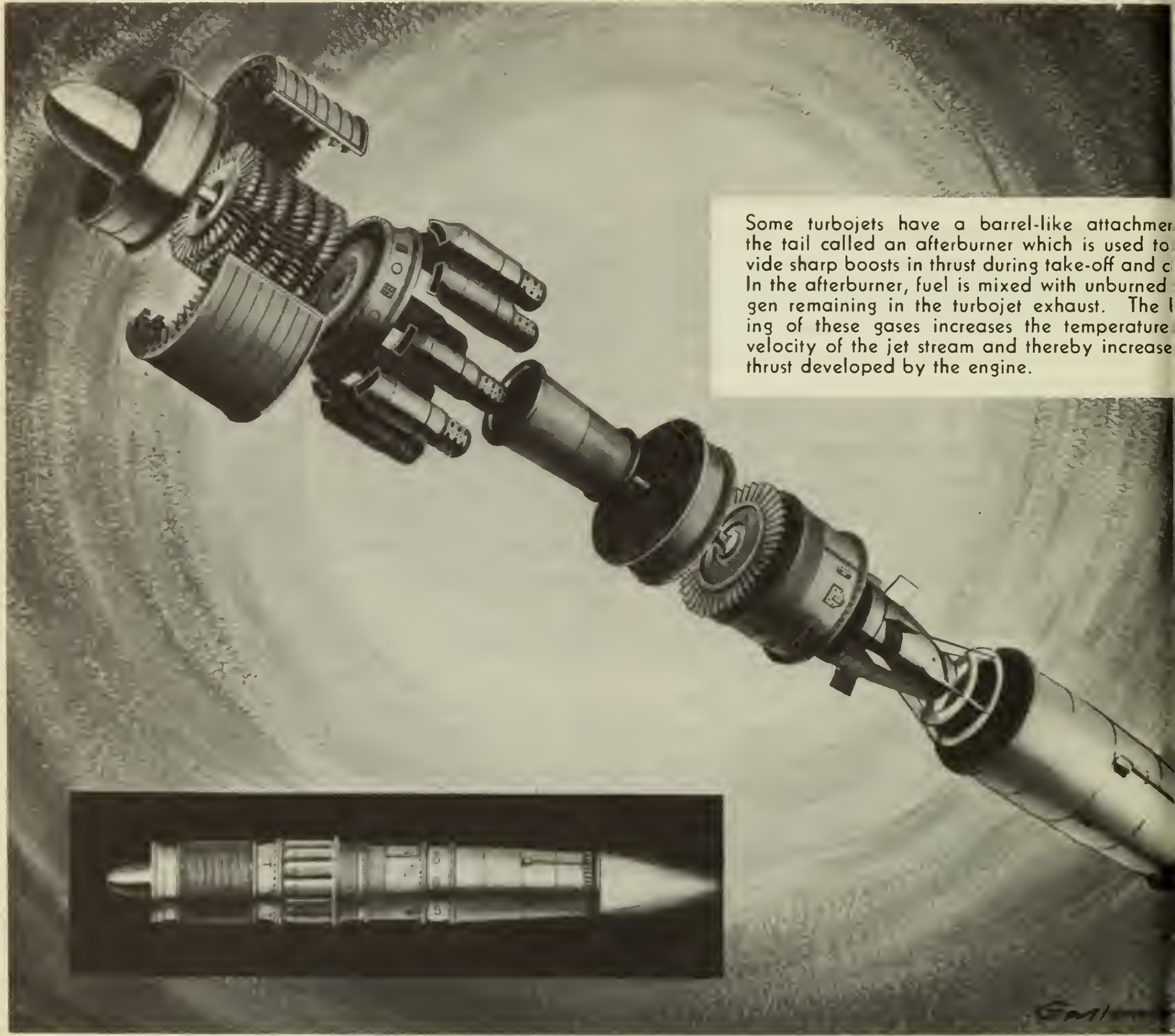
Some of the energy of the hot gases rushing toward the tail of the turbojet is used to turn the turbine which drives the compressor. The energy which is left in the gases after passing through the turbine produces the thrust.

The rotor and stator constitute a stage. Turbines are often designed with several stages. With such turbines, rotor speeds can be less while the diameter of the turbine assembly is kept reasonable small.

Since the compressor rotor and turbine rotor are mounted on the same shaft, the rotation of the turbine drives the compressor.

From the turbine, the exhaust gas rushes back through the converging exhaust nozzle, or tailpipe. There, because of the restricted opening, its velocity is increased and it leaves the engine at a velocity of about 1,800 feet per second.

The performance of a turbojet engine at altitude can be summed up by saying that the thrust decreases with altitude, and since less thrust is being developed, less fuel is used. At high altitudes where the density of the air is low, the drag of the aircraft is also low. The power required to propel the aircraft at any given true airspeed is proportionally reduced. Therefore, even though the thrust is less at higher altitudes, the aircraft can go almost as fast as it can at lower altitude where the thrust and drag are both much greater. Since the aircraft goes almost as fast at altitude as it does at sea level and since less fuel is required at altitude, the miles per pound of fuel are increased tremendously. In any mission where range is a factor, the turbojet engine must be oper-



Some turbojets have a barrel-like attachmen
the tail called an afterburner which is used to
vide sharp boosts in thrust during take-off and c
In the afterburner, fuel is mixed with unburned
gen remaining in the turbojet exhaust. The l
ing of these gases increases the temperature
velocity of the jet stream and thereby increase
thrust developed by the engine.

Courtesy of Ryan Aeronautical Company

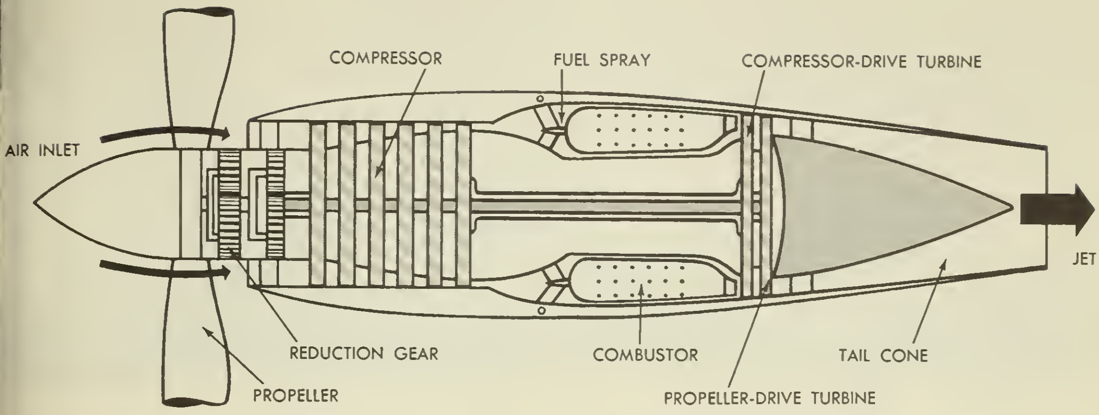
ated at high altitudes—that is, at 35,000 feet and above.

THE TURBOPROP ENGINE

Since much of the energy of the turbojet engine is lost in the wake of air behind the jet, engineers conceived the idea of using the same gas-turbine engine to drive a propeller rather than to produce a high velocity exhaust jet. The result is the turboprop engine.

The turbine engine used to drive a propeller is essentially the same as the turbojet engine. In the turbojet engine, however, only enough power is absorbed by the turbine to enable it to drive the compressor. Almost all the remaining energy is used to create the high-velocity jet. In the turboprop engine the turbine is designed to absorb all possible power from the hot gas, leaving only a very weak exhaust jet. The power produced by this turbine is more than enough to drive

Turboprop engine.



the compressor. The additional power is used to drive the propeller.

There are several different arrangements used for the turbine of the turboprop engine. The simplest arrangement is to have a multistage turbine mounted directly on the same shaft as the compressor and the propeller drive.

Another arrangement is the free-turbine engine. In this arrangement one turbine of sufficient size to drive the compressor is mounted on the same shaft as the compressor, and a second ("free") turbine is mounted on a separate shaft for driving the propeller.

Most gas turbine engines have operating speeds of 7,200 to 12,000 rpm. But propellers operate better at much slower rotations (800 to 1,500 rpm). It is therefore necessary, even with most reciprocating engines, to introduce considerable reduction gearing in order to make the propeller shaft run at a satisfactory speed. For a gas turbine engine, the amount of gearing necessary is considerable and not only adds weight to the engine but further complicates the design. Nevertheless, for certain kinds of aircraft it is worth it.

When compared with the exhaust jet of the turbojet, the propeller of the turboprop engine moves a much larger mass of air at a considerably lower velocity. This means higher propulsive efficiency at low aircraft speeds. A propeller-driven aircraft will therefore give superior performance during takeoff, climb, and long-range low-speed cruise.

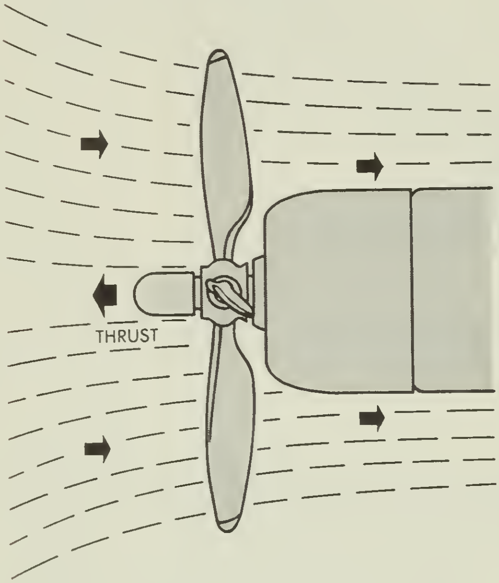
PROPELLERS

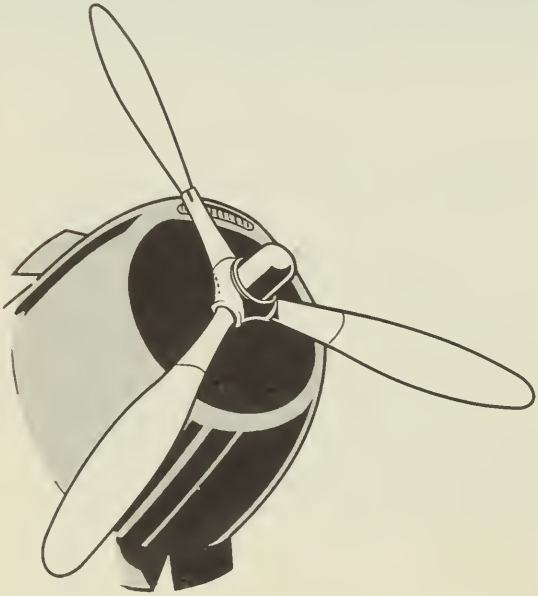
The rocket and jet achieve their forward thrust as reaction to propelling a mass of gas backward. A propeller achieves its forward thrust from exactly the same process.

The propeller acts upon a standing mass of air in such a way as to give it a velocity in one direction. The result is that a velocity in the opposite direction is imparted to the propeller, and to anything (such as an aircraft) fastened to it.

The propeller can be likened to an ordinary electric fan, except that the angle of the fan blades is reversed so that a fan accelerates air ahead of it into a room instead of rearward past the motor. Both fan and propeller work on the same principle. If the fan blades were rotated backward so the air was pushed back instead of forward, we would have the semblance of a minature airplane engine and propeller.

The air affected by a propeller is roughly equivalent to the area of the circle described by the turning propeller, so that the air moved rearward is in the form of a cylinder or tunnel of air.



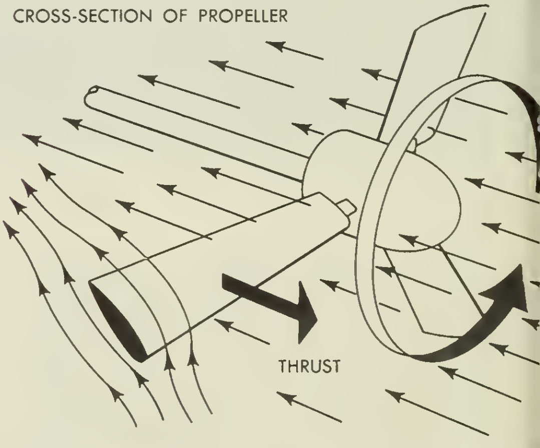


We may regard a propeller as a small wing. The cross section of a propeller blade is very similar to that of a wing, for each is an airfoil. A typical cross section of a propeller blade is shown below.

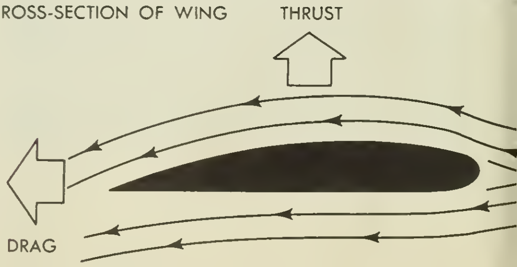
When the action of the propeller is explained in the light of a small cross section, the theory is known as the *blade-element theory*. A striking resemblance to the phenomenon of a wing cross section can be seen in the illustration. Acceleration of the air to the rear, forming the slipstream, corresponds to the downwash of a wing. Aerodynamically they are the same thing.

Normally a propeller is designed to produce thrust in proportion to the maximum horsepower of the engine. If a more powerful engine is designed, then a corresponding change must be made in the design of the propeller. The size of a propeller is limited by such factors as ground clearance and the speed of the propeller tip. One way to increase the thrust potential of a propeller is to increase the number of blades. If carried to extremes, however, the addition of blades can reduce efficiency. When a larger propeller is required, a compromise is usually made between diameter and number of blades.

CROSS-SECTION OF PROPELLER



CROSS-SECTION OF WING



Douglas-built U.S. Air Force C-133 turboprop transport. U. S. Air Force Photo

Propellers have been designed with three, four, and sometimes five blades.

The modern aircraft propeller is an extremely complex machine. In addition to being strong enough to produce the thrust required of it, it is designed so that the angle of attack of the propeller blade may be changed in flight. There are two principle reasons for changing the blade angle of a propeller during flight. A propeller without this controllable feature would operate efficiently only at or near the rpm and forward speed for which it was designed. By controlling the blade angle it can be made to function efficiently over a wide range of speeds and rpm. The second reason for controlling the blade angle is to keep the engine running at a constant rpm. The engine can thus be made to run at its most efficient rpm, its rpm of maximum power, or any other that is desired. This constant engine rpm is obtained by controlling the angle of the propeller blades with a device known as a governor.

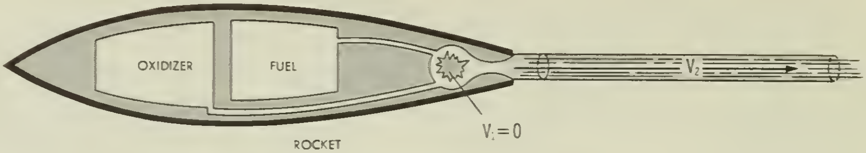
A propeller that incorporates a mechanism to control blade angle in flight is called a *controllable-pitch propeller.* If this mechanism is controlled by a governor to maintain a constant engine rpm it is known as a *constant speed propeller.* Propellers incorporating these features are installed in aircraft only when the added weight and cost of the installation can be offset by higher or more economical performance. A propeller of this type demands the highest order of craftsmanship in its construction and contains more moving parts than a modern, high-powered automobile engine.

The propeller for a turboprop engine requires very careful and specialized design. The gas turbine is practically a constant-speed engine, and therefore operates near its maximum power at all times. In this respect, it is quite different from a reciprocating engine, and it creates a major problem in the design of a suitable pitch control and governing mechanism for the propeller.

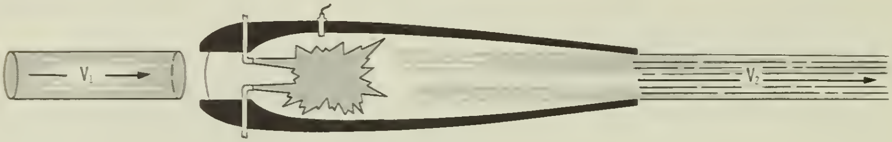
The 8,000 to 10,000 horsepower supplied to the propeller by a large gas-turbine engine is two to three times greater than the output of reciprocating engines in service today. A simple propeller capable of absorbing this power may have to be over 30 feet in diameter. Since this size is impractical, turboprops usually have specially designed four-bladed propellers. As more powerful engines are designed and built, it may become necessary to resort to two five-blade counter-rotating propellers—a very complicated, costly, and heavy mechanism.

Furthermore, to design and develop a pro-

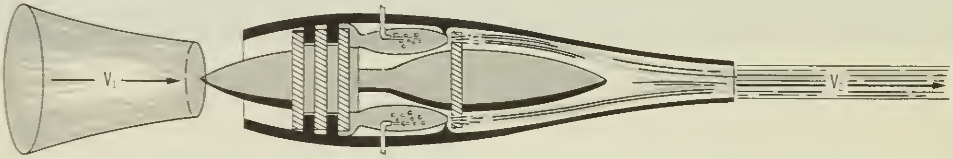
Volumes of air affected by different types of aircraft engines.



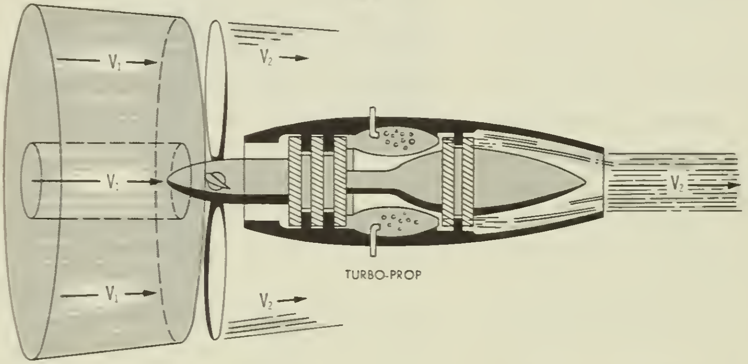
ROCKET



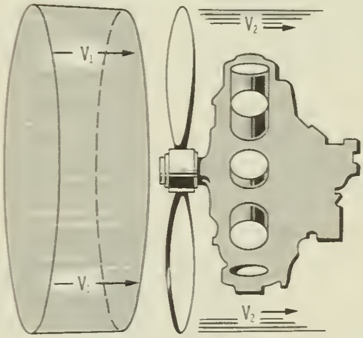
RAM-JET



TURBO-JET



TURBO-PROP



RECIPROCATING ENGINE AND PROPELLER

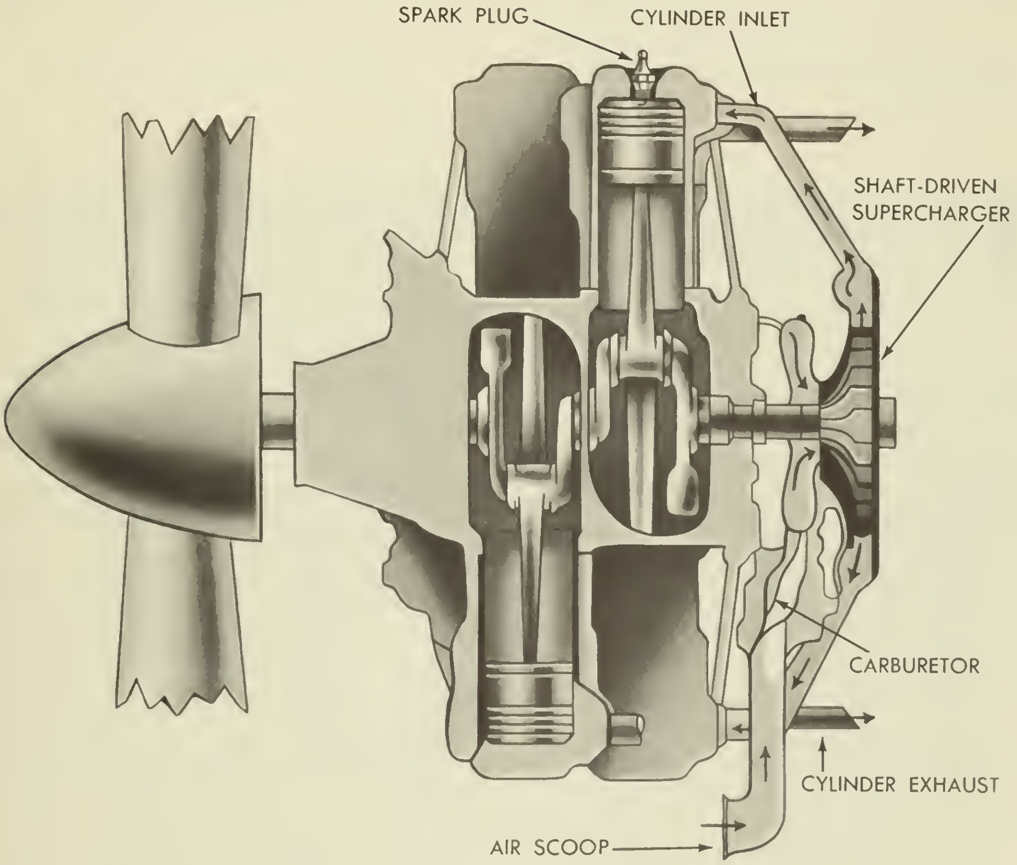
peller that is capable of absorbing 8,000 to 10,000 horsepower and that could fly an aircraft at speeds approaching that of sound presents a problem equal in magnitude to the development of the engine itself. The tip speed of a propeller depends on its rotating speed (rpm) and its forward velocity. If any part of the propeller operates at or near the speed of sound, shock waves will form on the blade, and the result will be a decrease in efficiency. When the aircraft is already traveling at a speed near that of sound, even a very small number of revolutions per minute will place not only the tip of the propeller but most of the blade in the undesirable transonic speed range. Propeller experts believe that the problem is not insurmountable. They have developed propellers that can absorb vast amounts of power and retain their efficiency at reasonably high speed. But such propellers are not ready for immediate use, largely because of the intolerable noise they create.

RECIPROCATING ENGINES

The reciprocating engine, with its cylinders, pistons, carburetor, and other familiar features, is still the most widely used aircraft power plant. Coupled to a propeller, it forms a propulsion system still unequalled for overall economy, flexibility, and reliability.

Its basic principle of operation is derived from the same law of action and reaction we have examined in the cannon, rocket, ramjet, turbojet, and turboprop. In fact, we see the law at work in *two* places in this propulsion system: in the action of the propeller shoving a mass of air backward so that the reaction force shoves the propeller in the opposite direction, and again in the cylinder where the piston is shoved downward by the explosion of the fuel-air mixture. The straight-line motion of the cylinder is turned into rotary motion by means of a crank arrangement as illustrated. The fundamental parts of the reciprocating engine are the carburetor, cylinders, pistons, connecting rods, crank shaft, spark plugs, and air-ducting system.

Redrawn from Solar



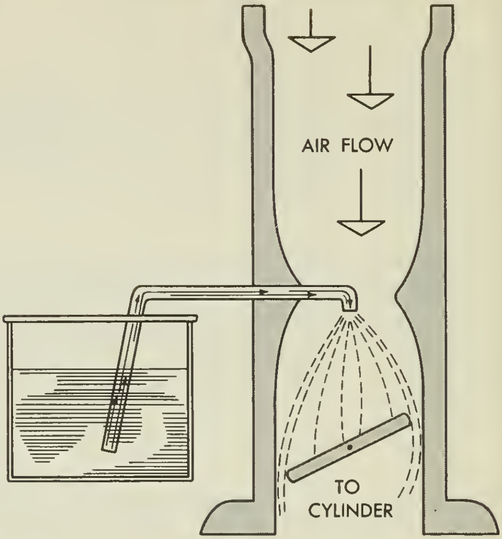
Cut-away drawing of a reciprocating engine.

The Carburetor

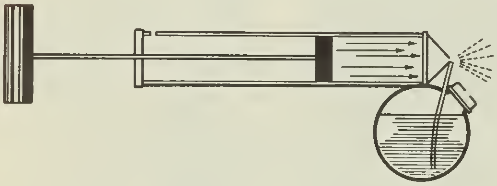
Liquid gasoline burns relatively slowly. For the kind of rapid combustion required in a reciprocating engine, the fuel must be in the form of a fog much like the spray from an insect spray gun. In this form, it is easily mixed with the proper amount of air for burning. The carburetor converts the fuel to fog form and mixes it with air. It also regulates the power by adjusting the fuel-air mixture and metering the flow.

As the load on the engine varies, the ratio of air to fuel must be changed even though there is no change in engine speed. When there is a high proportion of fuel to air, the mixture is said to be "rich." When this proportion is low, the mixture is said to be "lean."

To understand how the fuel is atomized (changed to fog), consider first an ordinary insecticide gun.



Simplified diagram of carburetor.



The spray-gun bowl contains the "fuel" and is comparable to the fuel bowl of the carburetor. Note the hole in the cap of the bowl: this vent allows the normal atmospheric pressure to enter the bowl. The top of the tube is located just below the air hole of the pump. Thus a stream of fast-moving air is directed across the top end of the tube.

As we have seen earlier, fast-moving air has a lower pressure than still air, so the pressure at this point is lower than the atmospheric pressure. The atmospheric pressure therefore pushes the "fuel" up out of the bowl and, when it meets the blast of air, it is mixed with the air and blown along with it as a spray or fog.

A carburetor operates in a similar manner, except that the lowered pressure at the air-fuel nozzle is achieved by speeding up the air flow with a Venturi tube. By constricting the throat slightly at the point where the fuel enters, the air can be made to flow faster and its pressure is thereby decreased. The fuel enters the airstream and is vaporized. The resulting mixture is then fed into the cylinder.

The carburetor described is the simplest type in use, but illustrates the general principle involved in all of them.

The larger the amount of air that the engine can handle per minute, the greater its horsepower output will be. Any method that increases the flow of air through the engine increases its horsepower output and also enables it to operate at higher altitudes where the air is less dense. Special mechanisms to aid in this are called superchargers. The supercharger is a blower or compressor which increases the mass of air intake of an engine over that which would normally be drawn in by the pumping action of the pistons.

Intake Stroke

This stroke takes place as the piston moves out of the cylinder toward the crankshaft. During this stroke the volume within the cylinder is increasing. At the same time, the lowered pressure within the cylinder allows the fuel-air mixture to be forced into the cylinder through the intake valve port, which is open.

Compression Stroke

As the piston reverses its direction and moves into the cylinder, the intake and exhaust valves are closed. The piston decreases the volume of the cylinder chamber and compresses the fuel mixture into a small space. Just before the end of this stroke, a spark from a spark plug ignites the fuel. Notice that both compression and ignition occur during this stroke.

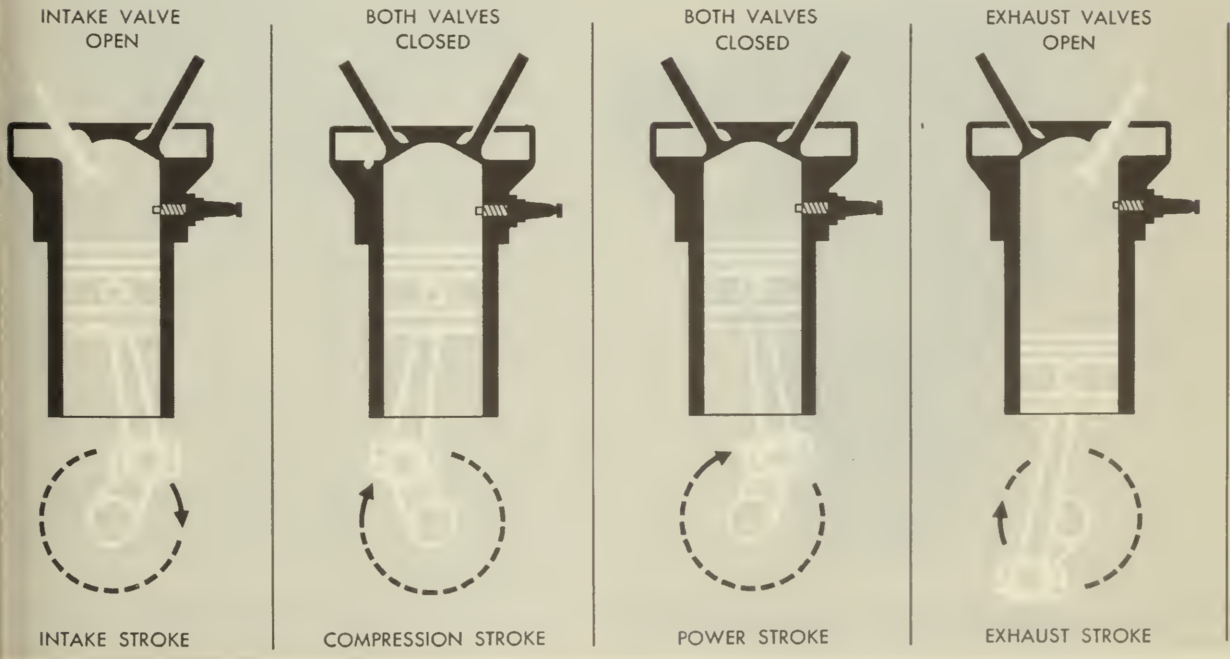
Power Stroke

The fuel is now burning and, as the piston again changes its direction of motion, the burning fuel forms a large volume of gas. The pressure cannot move the cylinder head, but it does move the piston. This is the power stroke.

Exhaust Stroke

When the piston has almost reached the bottom of the power stroke, the exhaust valve opens. Then, as the piston makes the fourth and last stroke of the cycle, it pushes the burned gases out of the cylinder. The cycle now is ready to begin again.

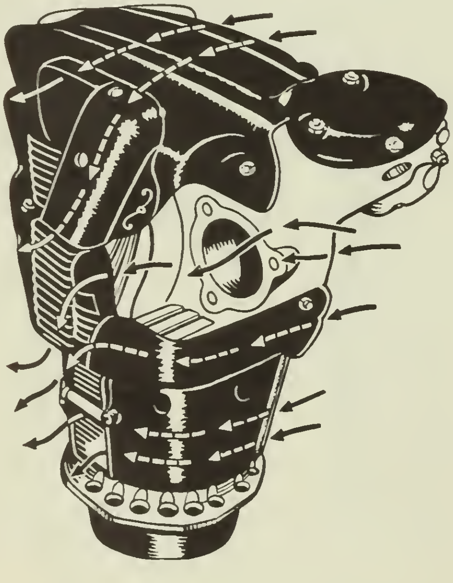
Four-cycle engine events.



Cooling

When the fuel-air mixture is burned in the cylinder, about a third of the heat produced is used to force the piston downward. About a third of the heat escapes through the exhaust valve and is lost to the atmosphere. But unfortunately the remaining heat is neither lost overboard nor used to perform work. It is trapped in the piston and in the walls of the cylinder. This heat must be dissipated and requires cooling of the engine and of the oil. There are two effective methods of cooling a reciprocating engine. The first is called air-cooling and is accomplished by letting the air flow over thin flanges or vanes machined on the cylinder head. This system alone is effective only at fairly low rpm, however, and several methods have been devised for assisting it. One of the most common is to construct a system of engine cowling, cowl flaps, and cylinder baffles in such a way that the incoming air must slow down to the velocity which does the best job of cooling.

The other method of cooling the cylinders is by the use of liquids as in an automobile. Liquid cooled engines are so constructed that a blanket of liquid entirely surrounds the cylinders. This liquid circulates from the engine, through pipes, to a radiator where it is cooled, then back through the engine block again. The usual liquids for cooling systems are water, ethylene glycol, or a mixture of the two. Both cooling methods—air-cooling and liquid-cooling—have certain inherent advantages and disadvantages. The air-cooled system is simpler, easier to maintain, and less vulnerable to enemy fire. The liquid-cooled system can usually be made with a smaller frontal area, is more compact, and its advocates claim that it cools more evenly and therefore better.



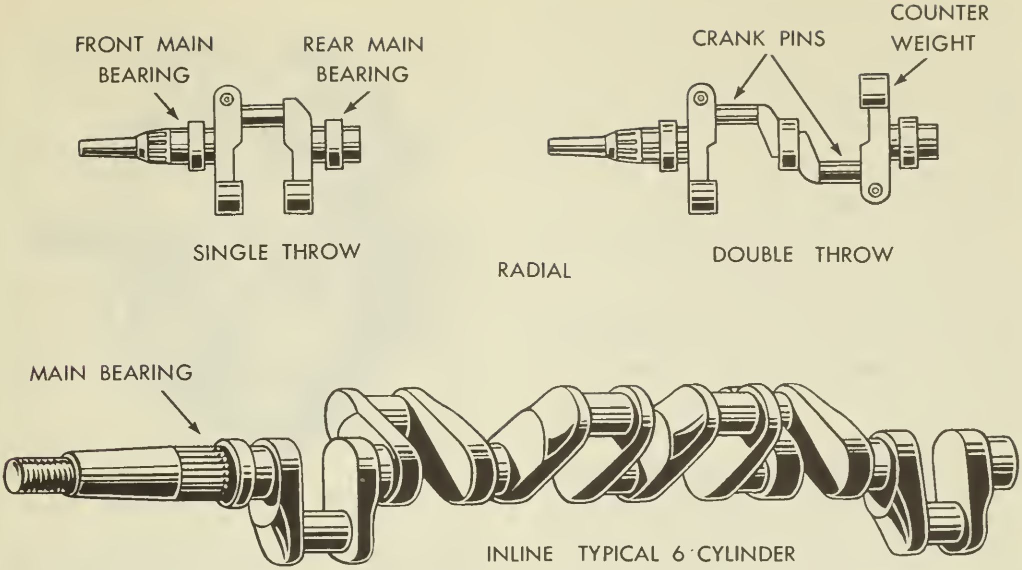
Vanes and baffles on an air-cooled cylinder.

Obviously, a single-cylinder engine would not be practical in an aircraft, any more than it would be in a modern automobile. Basically, there are two ways to raise the power output of an engine. One is to increase the individual cylinder size, and the other is to add more cylinders. Since there are very real limits to the practical size of a single cylinder and piston, the addition of extra cylinders has been found to be the most satisfactory way of increasing horsepower. As a result of this and other considerations, such as smoothness of operation, modern power plants are multicylinder affairs. Multicylinder engines have more power impulses per revolution than single-cylinder engines, and therefore give more sustained and smoother power. Aircraft engines have been constructed in many different configurations to provide this extra performance, but the most common today are the radial and the inline engines.

Inline Engines

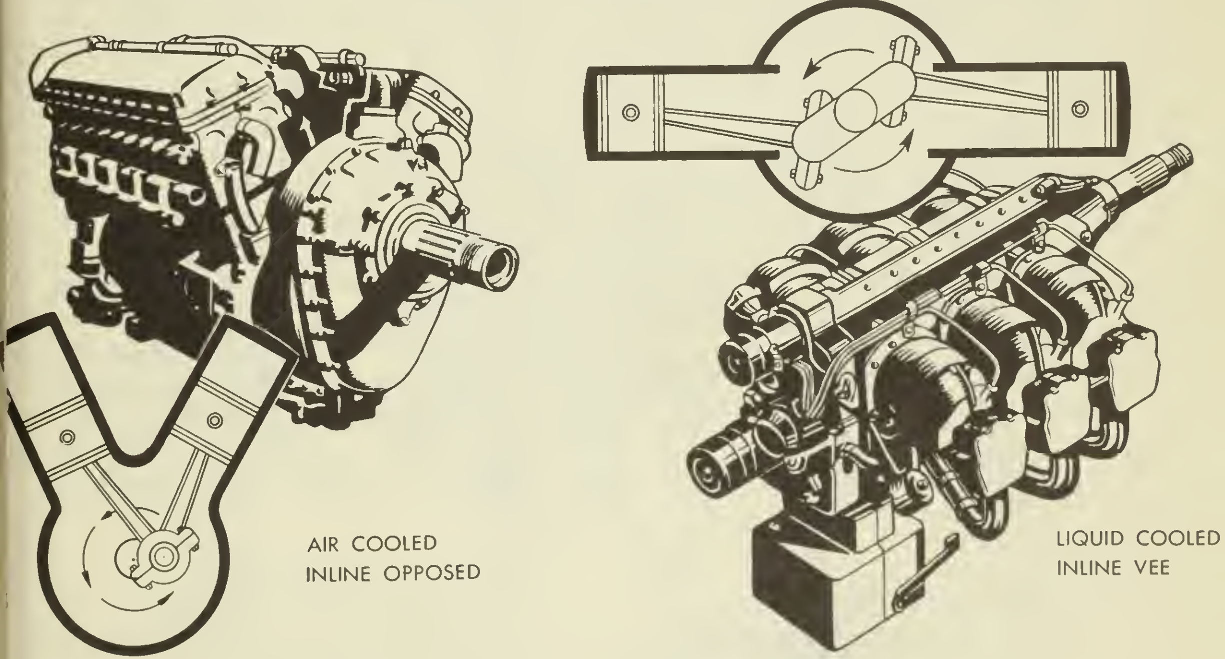
One method of adding extra cylinders to the basic engine is to increase the length of the crankshaft and make more throws or bends in it. Connecting rods and pistons are then connected to these bends. This will produce the basic type of engine known as the inline engine.

The inline engine can take many forms,



Typical engine crankshaft arrangement.

Typical inline engines.


AIR COOLED INLINE OPPOSED

LIQUID COOLED INLINE VEE

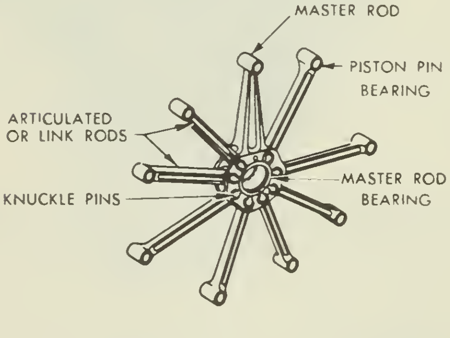
some of which are the "V", "X", and "W". Fundamentally these engines are all constructed in the same manner. In manufacturing the inline engine the individual cylinder heads can be cut separately or the entire row of cylinders may be cast in one block and then machined. If the engine is to be air-cooled, individual cylinders are usually cast separately. If the engine is to be liquid-cooled, the cylinders are cast in one long block.

Small inline engines such as those used to power light aircraft are usually air-cooled, while the larger, more-powerful ones are usually liquid-cooled. The reason for this is that the rear cylinders of large inline engines are extremely difficult to cool using the air-cooled system.

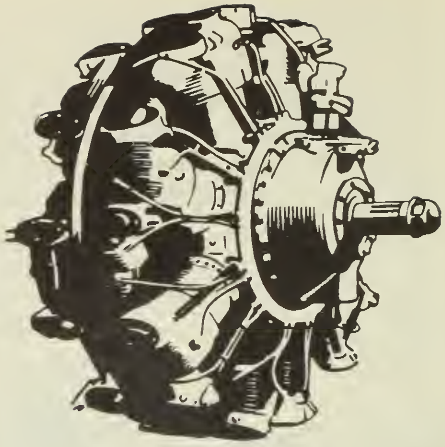
The inline engine offers a number of advantages that other engines do not have. It is usually a very compact installation with a small diameter. Also the liquid-cooled version offers very good, even cooling for the individual cylinders, which normally increases engine life and reduces engine failure.

Radial Engines

The other method of adding more cylinders to the basic engine results in the radial engine. In the common radial engine there is only one throw on the crankshaft and the crankshaft is not lengthened. Extra cylinders are arranged circularly around the crankshaft in such a manner that all the connecting rods operate from the single throw. The firing order for a 4-stroke cycle requires an engine which will always have an odd number of cylinders in each row or bank of cylinders. It is possible to build a 3-, 5-, 7-, 9-, 11-, or 13-cylinder radial engine, but never a radial engine with an even number of cylinders in one row (unless it is of the 2-stroke type). One of the cylinders is designated as a master cylinder. Its connecting rod fastens to the throw of the cylinders with a normal bearing. All of the other connecting rods operate on swivels around the bearing at the end of the master connecting rod. These connecting rods are known as articulated connecting rods.



Master and articulating rod assembly.



Single row radial engine.

The maximum number of cylinders in each row in a radial engine is usually nine. If additional power is required, one radial is connected to the rear of another to make what is known as a twin-row radial. Although still a radial, this will produce an engine with an even number of cylinders; but it is, in effect, two engines connected together. In this case the crankshaft will have two throws. By extending the crankshaft further it is possible to build radials with three, four, or more rows.

Because of their shape and size the majority of radial engines made in the United States are air-cooled, although liquid cooling has been used. The air-cooling system usually has the advantage of being comparatively simple, very sturdy and dependable, and much less vulnerable to enemy fire.

Operation and Characteristics

A propulsion system composed of a reciprocating engine and propeller is efficient at speeds up to approximately 400 miles per hour, and at altitudes under 40,000 feet. It will carry more weight farther and use less fuel than any other type of propulsion system in its speed range. It is dependable, and through the years of development has become rugged and simple to maintain. One of its best characteristics is its ability to create large thrust at low speeds, enabling the aircraft to make a relatively short takeoff run.

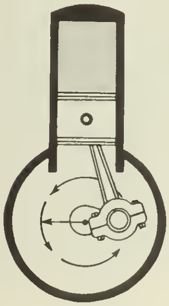
Such a propulsion system is also capable of very rapid acceleration. Its ability to change from a low to a high power output in a very short period of time has made the airplane a versatile and efficient military vehicle. The pilot can select any power setting he needs to maneuver or get out of trouble and get an immediate response from the engine.

The choice between radial engines and inline engines has produced a never-ending controversy. In Europe the aircraft designers have generally adhered to the liquid-cooled inline engines. During the last war large inline liquid-cooled engines were built by Allison, Packard, and Rolls-Royce and gave dependable service in United States and allied planes. In the United States today, however, the inline air-cooled engine is usually preferred for installations requiring less than 250 horsepower, while those needing over 250 horsepower are generally radial air-cooled.

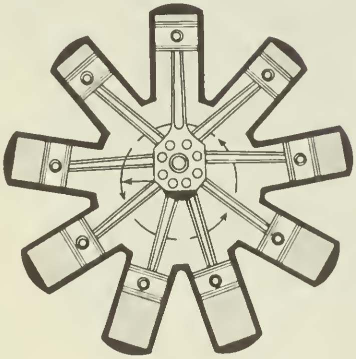
A reciprocating engine could probably be produced that would yield 8,000 to 10,000 horsepower, but it is extremely doubtful that such an engine of a reasonable size and weight could be made available in the immediate future.

Even if it were possible to develop a large reciprocating engine that could be used in high speed aircraft, the propeller would encounter difficulties, as was discussed earlier.

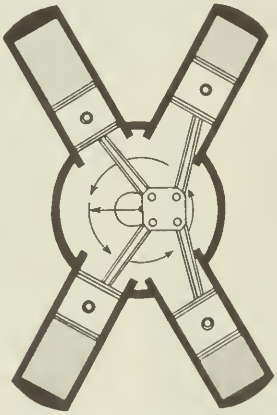
But the propeller-driven, reciprocating-engine propulsion system is very far from obsolete, and new and better aircraft are being designed every year to take advantages of its many desirable features.



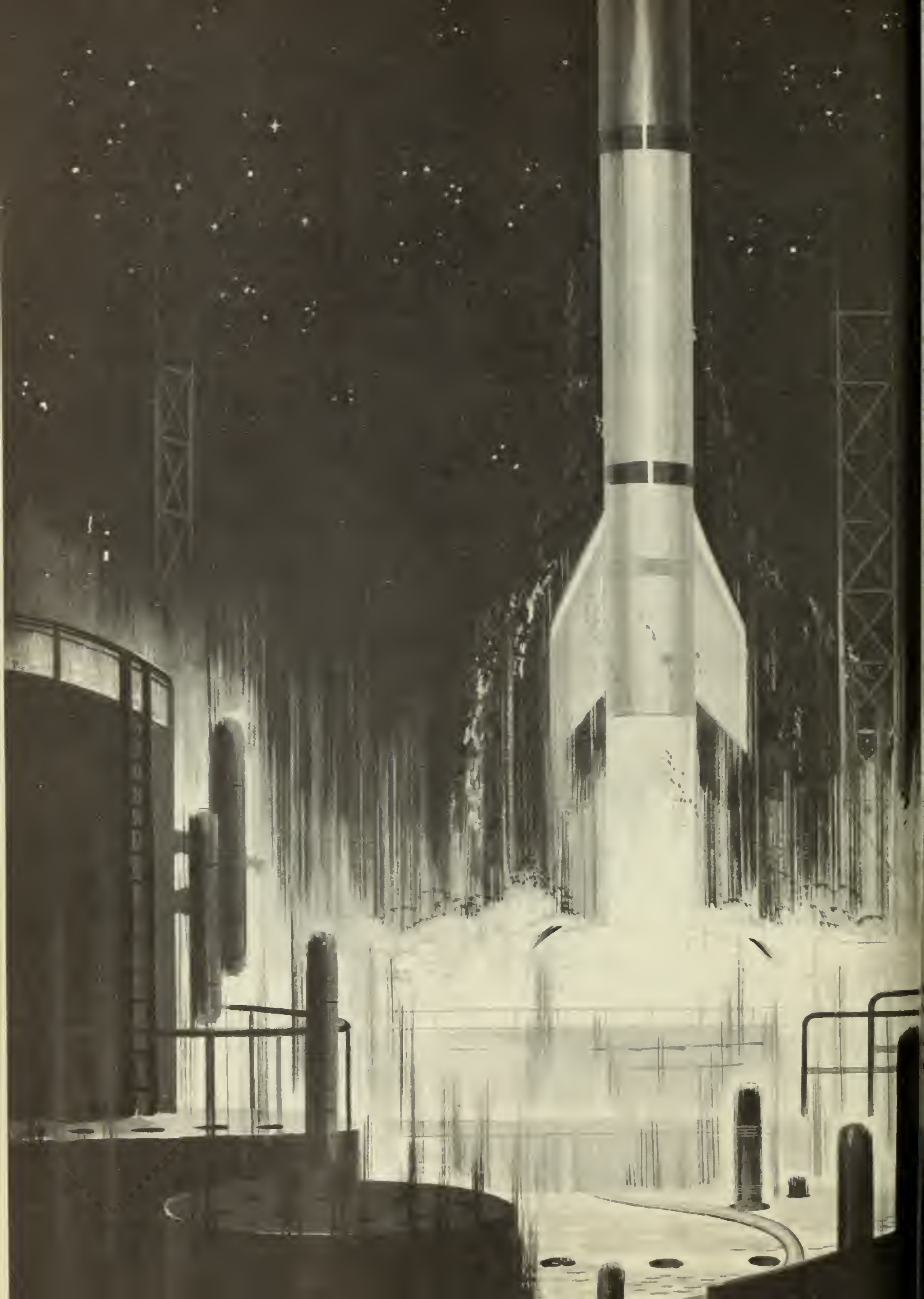
UPRIGHT
INLINE



RADIAL



"X" TYPE INLINE



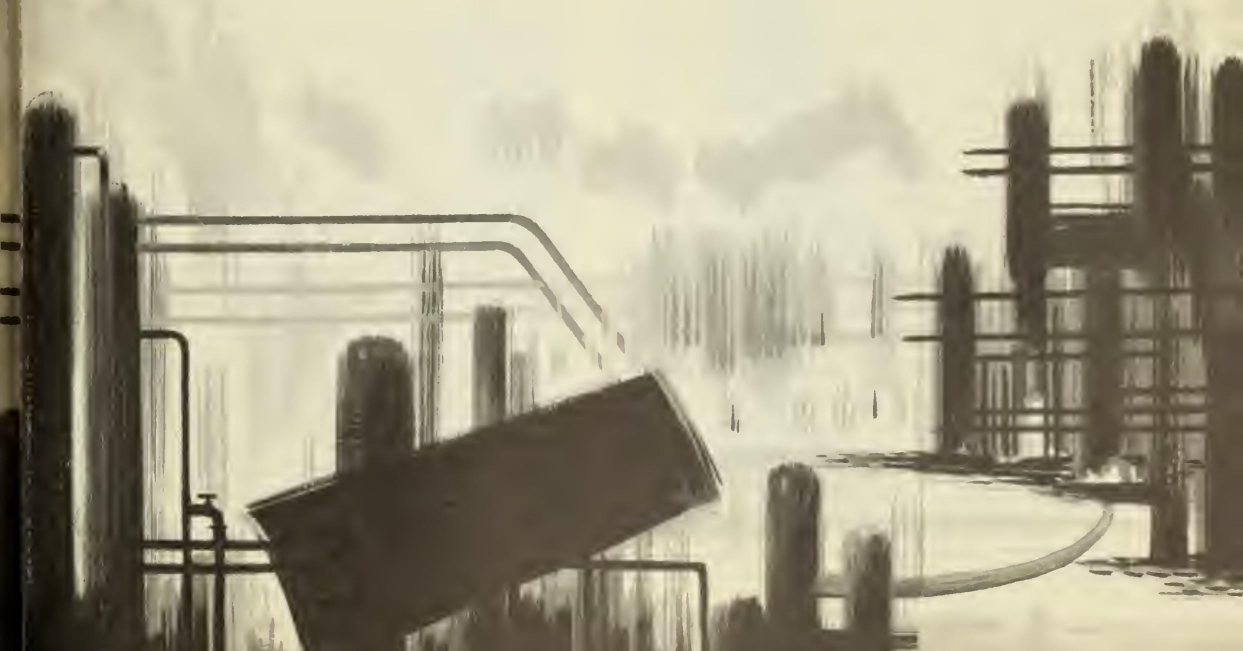
PART 2

CHAPTER 11

Space Vehicles

THOUGH CONVENTIONAL AIRCRAFT and balloons have flown in the outer fringes of the atmosphere, far greater altitudes have been achieved by test rockets, artificial satellites, and unmanned ballistic missiles. In addition to their uses as test vehicles for future weapons and transport craft, these space-traveling devices are collectors of scientific data concerning the cosmos. They have also been effective as vehicles of propaganda.

The significance of the fund of knowledge gathered by such vehicles is almost beyond the limits of man's imagination. It seems probable that many of the propositions now encountered only in science fiction will eventually take their places as accomplished facts or eminent steps towards manned space travel. The problems already visible are staggering and more appear every day. Gradually, however, the ingenuity and persistence of modern science are producing solutions.



TEST ROCKETS

The history of space flight began with the firing of test rockets. The first of these flying laboratories was sent to probe the upper levels of the atmosphere. Gradually, they have attained higher and higher altitudes until now they reach far beyond the earth's air ocean, into outer space.

Stages

To raise a pay load, whether it be instruments in a high altitude test rocket, a warhead in a ballistic missile, or animals or men and the equipment necessary for their continued survival, is costly in fuel. Pay loads must not be encumbered by empty fuel containers, fuel pumps, early stage controls, and heavy plumbing: These must be jettisoned as soon as empty. This accounts for the use of stages in rocket firings. In effect, segments of used equipment are discarded when they are no longer useful. The first successful satellite launcher used three stages; as many as five have been designed for other flights.

Structural Problems

The highest degree of engineering skill is needed when designing space vehicles. The prime structural requirement is maximum strength with the least possible weight. Just one example of ingenuity in dealing with this requirement is the integral rocket fuel tank. The skin of the tank is likewise the skin of a portion of the rocket, and the fuel, under pressure, gives it the necessary rigidity.

Materials are as important as ingenuity. For example, metals and their characteristics must be scrutinized with particular attention to their abilities to retain strength under conditions of great stress and when temperatures are raised near the melting point by air friction or exhaust heat. Structural problems multiply rapidly with the demands for higher performance and greater size. Here, practical problems sometimes take precedence over theoretical problems.

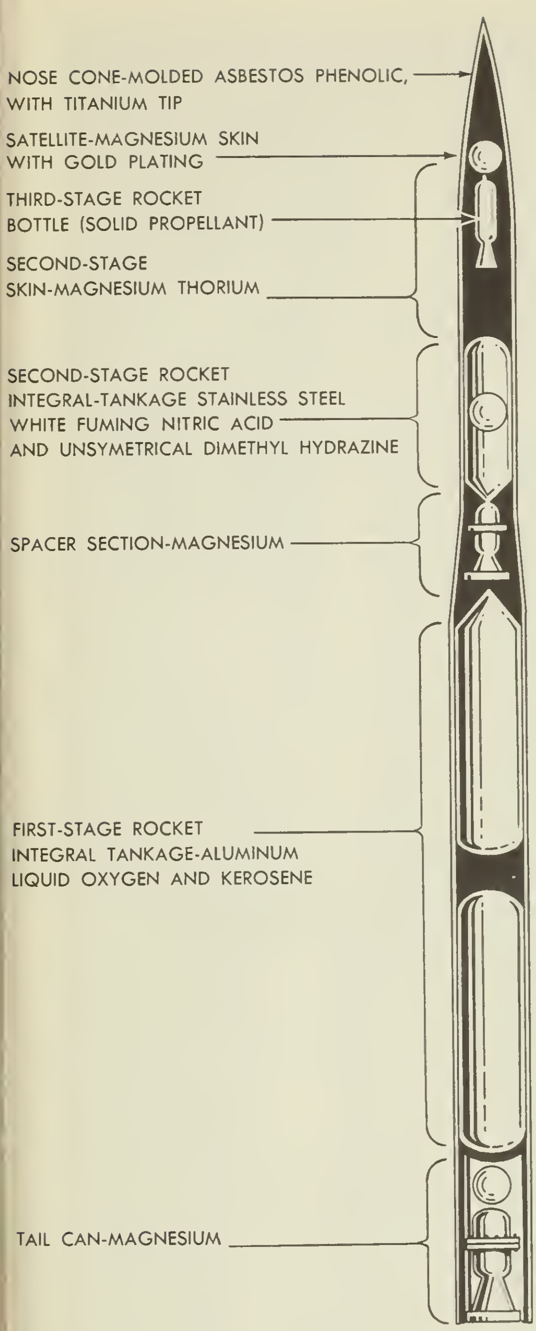
A scientist may solve a theoretical problem by calling for the use of beryllium, a metal six times stronger than steel on a strength-to-weight basis, and which withstands tremendous heat. But the machinist knows that beryllium is too hard and brittle to be worked by practical methods—and anyway, the world's entire supply of refined beryllium can be carried in a briefcase.

Controls

The various triggering devices needed for successful test rocket firing must operate with near-perfect precision. Some are activated by passage of time, some by sensitivity to altitude, velocity or heat, and some at completion of the previous step in a sequence. Some operate on a signal from outside the vehicle. For example, when the fuel in the first stage of a high altitude rocket is exhausted, explosive bolts are automatically detonated which "shuck off" the exhausted portion. As the propellant in the second stage is exhausted, small auxiliary rockets are automatically activated which impart a spin to the third stage and disengage it from the second stage carcass. The third stage, now well out of the atmosphere which made fin controls feasible, is now dependent on the spin for maintenance of lateral stability. Once the fuel in the third stage is exhausted, a spring or other device is activated which shoves the pay load forward and free.

Space vehicles are usually launched straight up from the earth's surface. The chief reason is that the vehicle will thus traverse a minimum depth of atmosphere, saving fuel and generating a minimum of heat from atmospheric friction. Another reason is the relatively fragile construction of many rockets, which could not withstand the stresses of lateral suspension before firing. Control problems are simplified, too, when the take-off is vertical.

Typically, a high altitude rocket stands on its base alone just before firing. As the rocket rises from the launching "pad," tendencies to nose-over must be counteracted. World War II German V–2 rockets used atmospheric stabilizing fins and gyro-

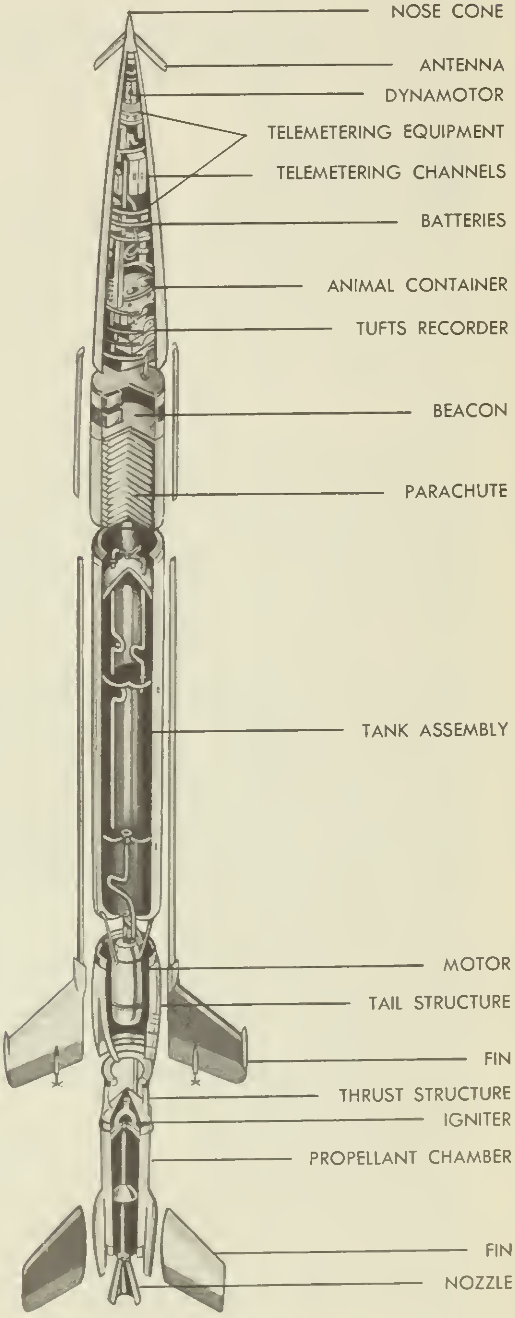

NOSE CONE-MOLDED ASBESTOS PHENOLIC, WITH TITANIUM TIP
SATELLITE-MAGNESIUM SKIN WITH GOLD PLATING
THIRD-STAGE ROCKET BOTTLE (SOLID PROPELLANT)
SECOND-STAGE SKIN-MAGNESIUM THORIUM
SECOND-STAGE ROCKET INTEGRAL-TANKAGE STAINLESS STEEL WHITE FUMING NITRIC ACID AND UNSYMETRICAL DIMETHYL HYDRAZINE
SPACER SECTION-MAGNESIUM
FIRST-STAGE ROCKET INTEGRAL TANKAGE-ALUMINUM LIQUID OXYGEN AND KEROSENE
TAIL CAN-MAGNESIUM

Schematic of the three-stage "Vanguard" earth satellite launching vehicle with its propellant and structural materials indicated. Note that each rocket in the vehicle uses different propellants. Guidance mechanism (not shown) which controls the complete vehicle during flight is located in the second stage. All together, the three stages give the vehicle an overall length of 72 feet. On March 17, 1958, the Vanguard successfully launched its first satellite into orbit.

Based on drawing from K. W. Gartland, "The Vanguard Project,'

Spaceflight 1, 1 (Oct 56) p. 24

Air Force Aero Medical "Aerobee" rocket used in high altitude biological research. The pressurized nose cone is divided into a forward section containing the telemetering equipment, and a rear section in which a monkey, a steel mouse-cage, and a camera can be placed side by side. The parachute enables the animals to return safely to earth. Animals fired aloft to heights of nearly 200,000 feet have generally suffered no ill effects and have provided much valuable data on the medical aspects of upper-atmosphere flight.



controlled carbon vanes mounted in the blast of the rocket engine to alter or correct direction. Many later rockets have abandoned fins entirely, and depend for all directional controls upon gimbal-mounted engines. That is, the rocket chamber and nozzle are swiveled to provide corrective thrusts. In this way, rocket power balances the rocket as a finger might balance a baseball bat. These gimbal-mounted engines also may be used for deliberate turning of the vehicle in flight.

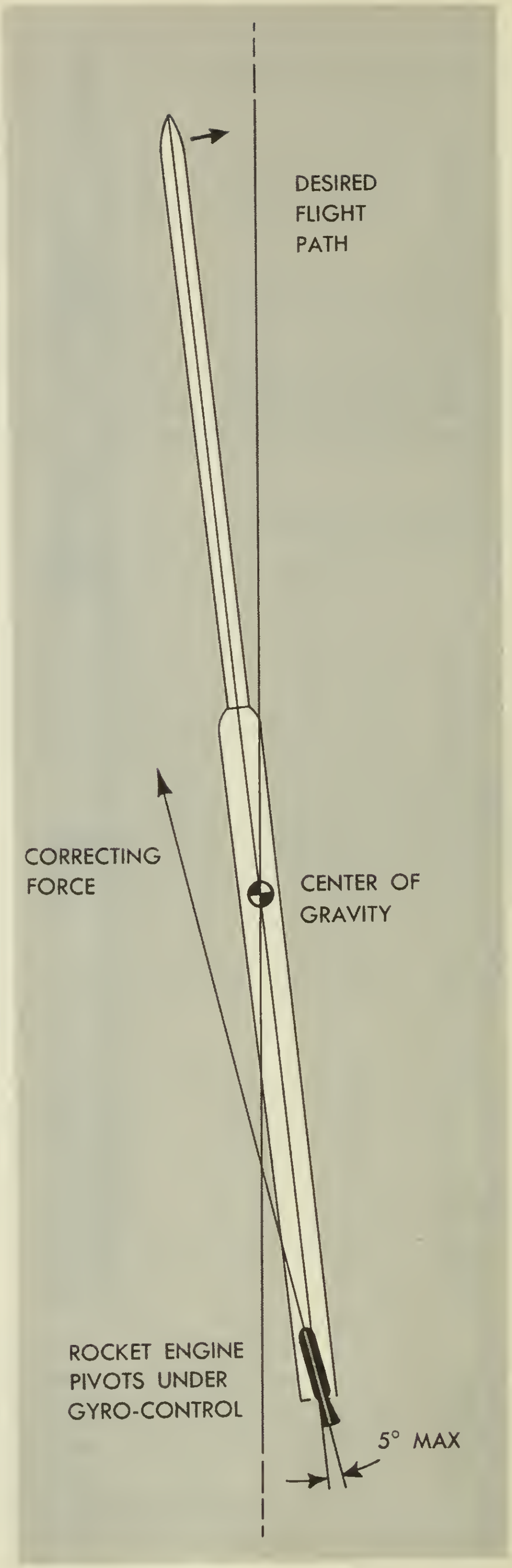
Escape Velocity

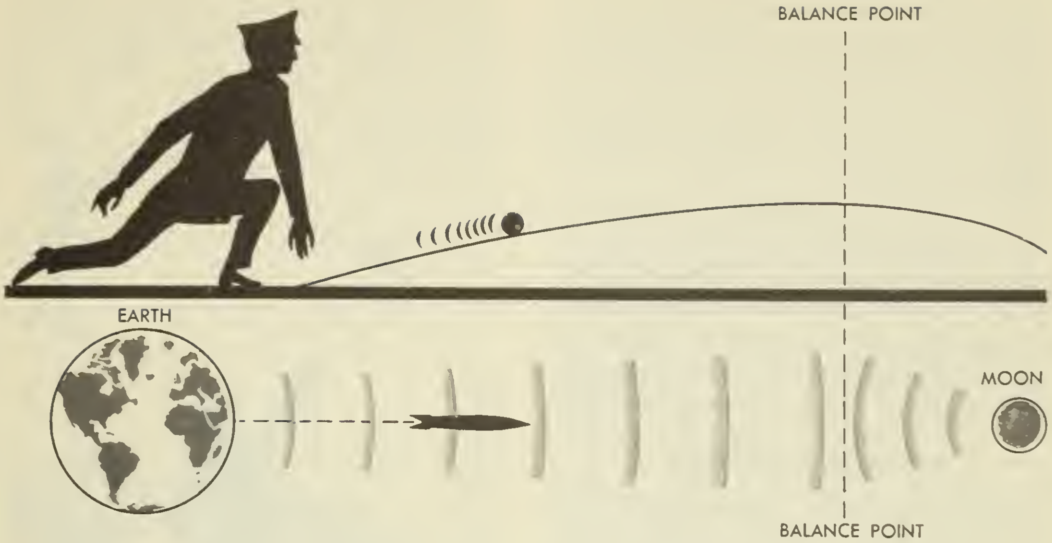
Every large body has an escape velocity proportional to its mass. For the earth, if we assume that the total velocity is imparted to a vehicle right at ground level, directed straight up, it is 25,000 mph (seven miles per second). The escape velocity from the less massive moon, however, is only 5,400 mph.

Actually there is no theoretical reason why a space vehicle could not proceed at a good safe elevator speed of 20 mph for the entire distance. The prohibitive factor in this, aside from the unreasonable length of time it might take to complete a journey, is that propulsive force would have to be applied every inch of the way that the earth exerts gravitational pull. It is only possible to think practically of escaping from the gravitational pull of a mass as great as the earth by attempting speeds away from it at 25,000 mph or greater. Large propulsive forces applied for only a few seconds or minutes will do the job.

Of course, the earth's gravitational pull decreases at high altitudes, but the amount is not appreciable except at great distances. At 200 miles, it has decreased only about 10 percent, and at 4,000 miles it is still about a quarter of its sea-level value.

The problem of escape may be compared to rolling a ball up a hill. If the ball is not given enough initial velocity, it will gradually slow down, stop before it reaches the top of the hill, and roll back down. But if the initial velocity is great enough, it will





roll to the top and then down the other side—which may be compared to a missile "escaping" from one gravitational field and "falling" toward that of another planet or satellite. The accelerations need not be tremendous, though the lower the acceleration rate, the longer it will take the vehicle to reach escape velocity. Accelerations in the order of ten *g*'s (ten times the acceleration of the earth's gravity) are probably maximum, since greater forces would impose destructive stresses on the vehicle's structure. Two or three *g*'s are probably more practical figures.

The speeding vehicle, once propulsion ceases, immediately begins to slow because of the earth's gravitational pull. However, before it can slow a great deal, the vehicle will have reached a considerable distance from the earth. At that distance, the earth's gravitational pull is less, so that the vehicle's remaining momentum is sufficient for it to continue. This will then be true at any distance from the earth. Eventually other heavenly bodies such as the moon or sun will exert stronger gravitational pulls, and the vehicle will begin to "fall" towards one of those bodies.

Uses for Test Rockets

The first test rockets were used, logically enough, to test rockets. Such tests are continuing, at constantly increased distances from the earth. The practicality of rocket engines for many purposes in both war and peace is now assured.

Test rockets are also launched for other tests and measurements. For example, they carry instruments for collecting, measuring and recording flight data. Rockets have also been used to carry instruments which measure the density of the atmosphere's various layers, and to learn more about the degree of ionization of molecules in these layers. The strengths of ultraviolet and radio waves emanating from the sun can be measured, as well as cosmic rays coming from outer space. Test rockets are helping us to learn the degree to which the earth's electromagnetic forces vary, the distances and the number of orbiting asteroids between the earth and the moon, and the prevalence of meteoric dust and other cosmic particles. Rockets are also used to investigate the possibility of making very long range weather forecasts with the aid of data and pictures obtained from high altitudes.

Photographs of the sun, planets, and stars taken with cameras outside the distorting atmospheric blanket give us more exact information about them. Invaluable astronomical data can be drawn from photographs of the far side of the moon, formerly hidden from view.

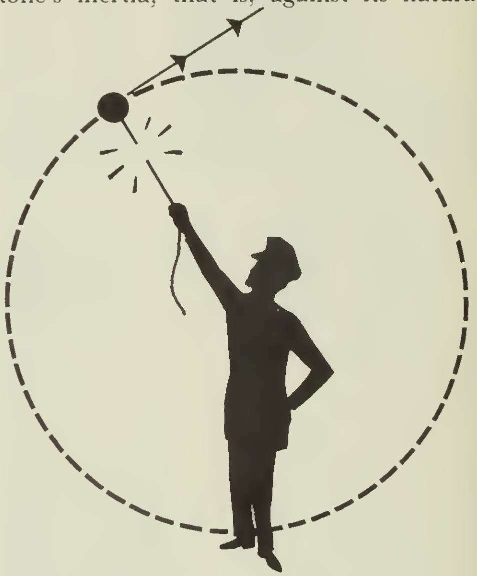
Of course, test rockets are necessary devices in developing improvements in the propulsion and control of intercontinental ballistic missiles and also in adding to our understanding of the problems of establishing orbiting satellites and space platforms, and of making trips to the moon and beyond.

ARTIFICIAL SATELLITES

No better analogy has been used to describe the forces which hold a satellite to its course than that of the stone whirled around at the end of a cord. Imagine such a stone whirling in atmosphereless space.

At any given point in time, the stone has a certain velocity in a certain direction. But the natural laws of motion require that a freely-moving body travel in a straight line. If we assume the stone to have a velocity of 10 feet per second, and if no other forces are applied to it, it will continue at that speed in a straight path. In order to turn it from that path, a force must be applied to it. This force is supplied by the hand and transmitted to the stone by the string.

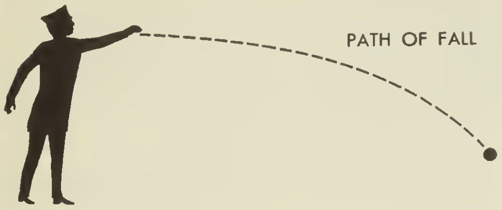
Do not attempt to understand this situation in terms of "centrifugal force." There is *no* radial force pushing the stone away from the center of the circle. The string's pulling force works against the moving stone's inertia, that is, against its natural tendency to continue in a straight path. If the string breaks, the stone will not fly off in the direction the string is pointing, but in the direction the stone was traveling at that moment, that is, at a tangent to the orbit.

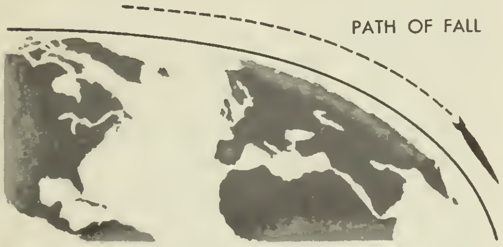


If we replace the hand by the earth, the string by the earth's gravitational force, and the stone by a satellite, the same laws of physics will apply.

The analogy is similar in another respect, too. You know that if you whirl your keys on a long key chain, the speed of rotation can be slower than if you try to whirl them on a mere inch or two of chain. A satellite orbiting about the earth just outside the atmosphere needs a velocity of about 18,000 mph to have enough straight-line inertia to balance the earth's gravitational force. But if the orbit is larger, the speed required will be lower, and at 1,000 miles from the earth's surface, it need be only 15,800 mph. At 22,000 miles it will be only 6,840 mph. The moon, still our best-known satellite, orbits the earth at about 240,000 miles and travels only 2,355 mph in making its 28-day circuit.

A satellite orbiting in a circle is constantly falling toward the earth, but its horizontal speed is so great that, in any given period of time, its fall only brings it around to a new point which is at the same altitude.



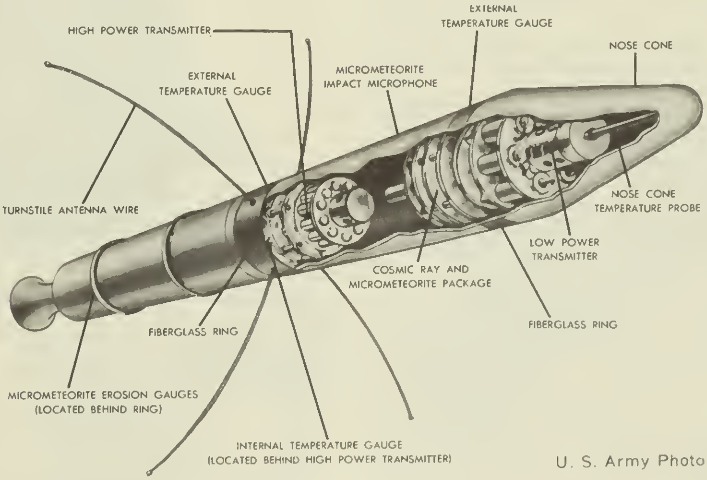


This is a very delicate balancing of forces and the tiniest additional force applied to the satellite will upset it.

Since an object in free fall is weightless, a slight outward push would send the satellite off its orbit and out into space. A slight increase in its velocity would give it greater straight-line inertia and produce the same result. And if a slight additional force were applied to it toward the earth, the satellite would either descend to a lower altitude and establish a new orbit, or change the shape of its orbit, perhaps to one which would intersect the earth's surface.

If the satellite's velocity through space is slightly decreased by air friction, its inertia will be slightly decreased, too. In this case, the balance between inertia and gravity will be upset in favor of gravity, and the satellite will descend. Since orbital velocities are greater at lower altitudes, the satellite's speed will increase. This will compound the friction and heating problem and the vehicle may either burn or melt away.

The mass, shape, or size of a satellite is not pertinent once its orbit is established in atmosphereless space. Any increase in mass increases its inertia, but this is counteracted precisely by added gravitational pull on the mass. Shape and size likewise cannot affect a satellite's speed or staying power unless there is air or other friction to act upon them.


HIGH POWER TRANSMITTER
EXTERNAL TEMPERATURE GAUGE
EXTERNAL TEMPERATURE GAUGE
MICROMETEORITE IMPACT MICROPHONE
NOSE CONE
TURNSTILE ANTENNA WIRE
NOSE CONE TEMPERATURE PROBE
LOW POWER TRANSMITTER
COSMIC RAY AND MICROMETEORITE PACKAGE
FIBERGLASS RING
FIBERGLASS RING
MICROMETEORITE EROSION GAUGES (LOCATED BEHIND RING)
INTERNAL TEMPERATURE GAUGE (LOCATED BEHIND HIGH POWER TRANSMITTER)

U. S. Army Photo

A model of the 6.4-inch, four-pound "Vanguard" satellite that went into orbit March 17, 1958. The power to transmit "beeps" back to the earth is furnished by solar powered batteries which harness the sun's rays through small windows.

"Viking" test rocket shortly after take-off. Data obtained from firings of this one-stage rocket played an important part in the ultimate success of the "Vanguard."

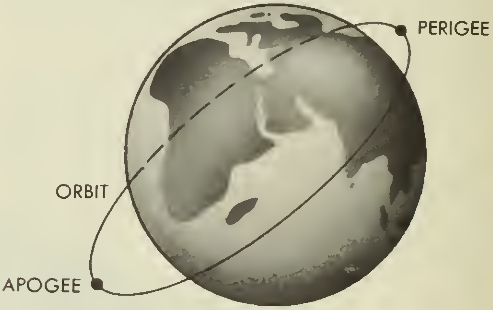
Launching a Satellite

If we shoot a satellite into orbit in an easterly direction, we can take advantage of the fact that, while it is sitting "at rest" on its launching pad, it is already spinning around the center of the earth mass at the speed of rotational travel of the earth's surface. At the equator, this is quite appreciable—1,000 mph. Thus, less energy need be applied to put a satellite into such an orbit.

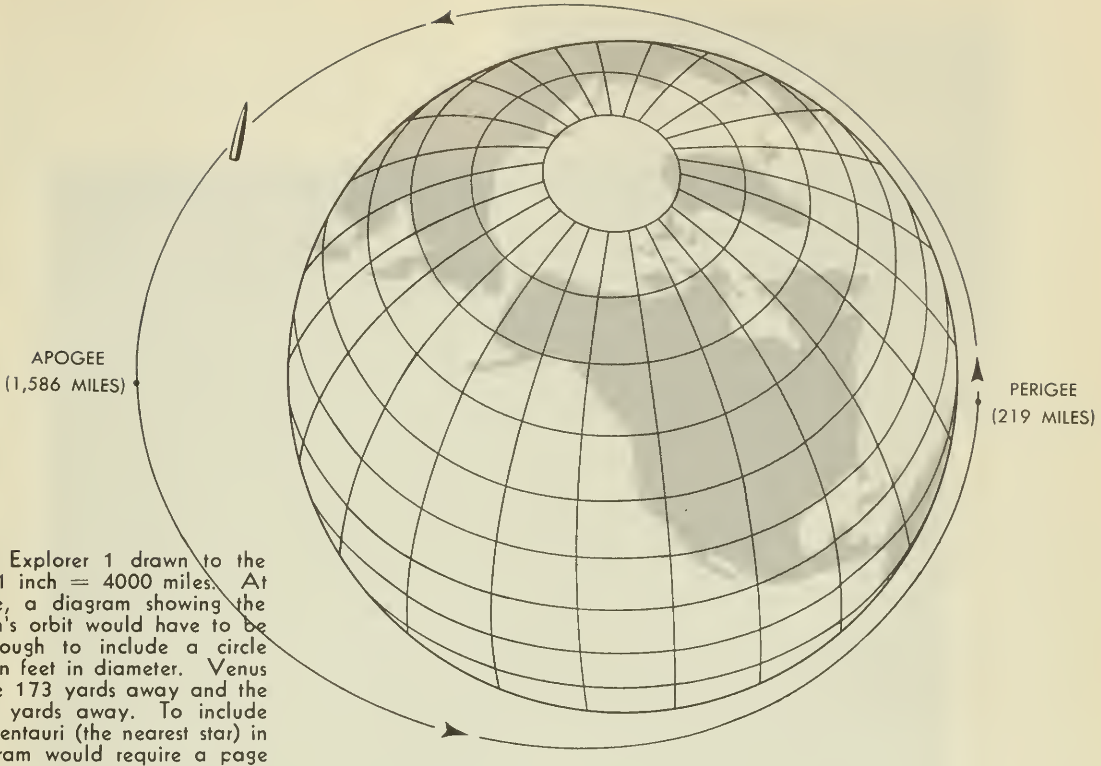
If an eastward-traveling satellite is orbited at a distance of 22,000 miles from the earth's surface, its time of revolution about the earth will be 24 hours. Consequently, if launched on the equator and directed eastward, the satellite would remain fixed in the sky relative to a point on the earth. Such a satellite would have many practical uses.

Satellites follow generally elliptical paths around the heavenly bodies which hold them gravitational prisoners. Orbit shape may be almost circular to very elongated. The degree to which the orbit diverges from circular is spoken of as the *eccentricity* of the orbit. Even though satellites are prisoners of one central mass, they are gravitationally affected by other masses in the heavens which make them diverge slightly from true elliptical paths. Other divergencies are caused by the fact that the earth is not entirely spherical, because the earth's mass distribution is not perfectly even, and for other reasons.

That point of the orbit which reaches farthest away from the center of the mass which holds the satellite is called the *apogee.* The opposite point, where the orbital path is closest, is called the *perigee.* As a satellite approaches apogee in its orbit, it slows down. Approaching perigee, it increases in speed. This can be explained most simply by considering that the mass approaching apogee is opposing gravitational force, while it is "falling" when approaching perigee. It is near to perigee that earth satellites are most likely to encounter significantly destructive masses of atmospheric molecules.

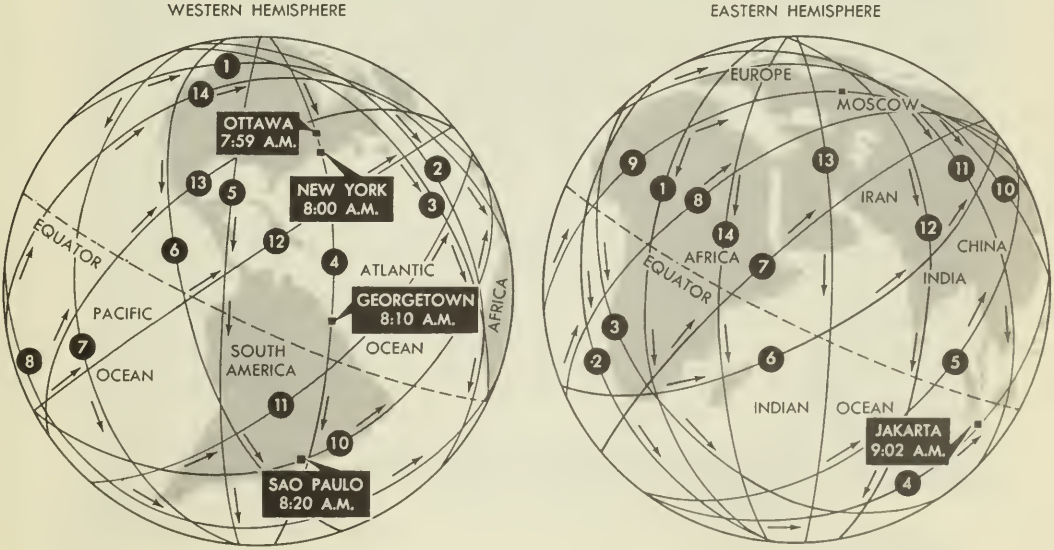


Satellite orbits remain in a plane, except as influenced laterally by perturbation forces. An earth satellite established in orbit elsewhere than along the line of the earth's equator does not therefore pass over the same portions of the earth's surface in succeeding revolutions; the earth is rotating beneath it. This accounts for the characteristic grid appearance of a satellite's path when it is charted on model or paper.

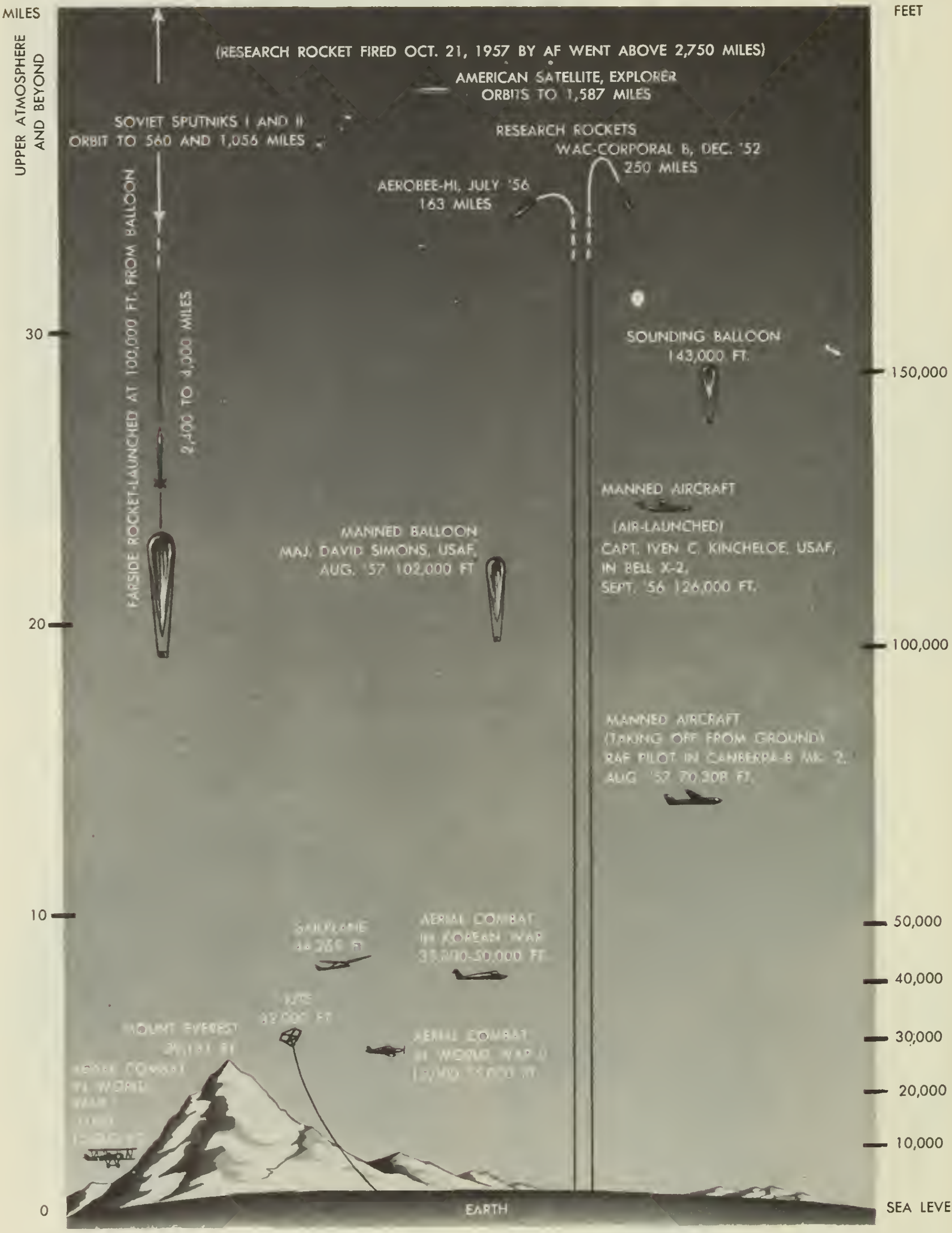


)rbit of Explorer 1 drawn to the cale of 1 inch = 4000 miles. At his scale, a diagram showing the he moon's orbit would have to be arge enough to include a circle early ten feet in diameter. Venus vould be 173 yards away and the un 634 yards away. To include Alpha Centauri (the nearest star) in he diagram would require a page eaching about two-fifths of the way o the moon.

The Track of Soviet Sputnik 1.



Courtesy of New York Times


MILES
UPPER ATMOSPHERE AND BEYOND
FEET
(RESEARCH ROCKET FIRED OCT. 21, 1957 BY AF WENT ABOVE 2,750 MILES)
AMERICAN SATELLITE, EXPLORER ORBITS TO 1,587 MILES
SOVIET SPUTNIKS I AND II ORBIT TO 560 AND 1,056 MILES
RESEARCH ROCKETS
WAC-CORPORAL B, DEC. '52 250 MILES
AEROBEE-HI, JULY '56 163 MILES
FARSIDE ROCKET-LAUNCHED AT 100,000 FT. FROM BALLOON
2,400 TO 4,000 MILES
SOUNDING BALLOON 143,000 FT.
MANNED AIRCRAFT (AIR-LAUNCHED) CAPT. IVEN C. KINCHELOE, USAF, IN BELL X-2, SEPT. '56 126,000 FT.
MANNED BALLOON MAJ. DAVID SIMONS, USAF, AUG. '57 102,000 FT
MANNED AIRCRAFT (TAKING OFF FROM GROUND) RAF PILOT IN CANBERRA-B MK. 2, AUG. '57 70,308 FT.
SAILPLANE 44,255 FT
AERIAL COMBAT IN KOREAN WAR 35,000-50,000 FT.
KITE 32,000 FT
MOUNT EVEREST 29,141 FT
AERIAL COMBAT IN WORLD WAR II 15,000-35,000 FT
AERIAL COMBAT IN WORLD WAR I [illegible] 15,000 FT
EARTH
30
20
10
0
150,000
100,000
50,000
40,000
30,000
20,000
10,000
SEA LEVEL

Courtesy of Air Force Magazine, March 1958

The Satellite and Its Rocket

The amount of fuel required for rocket propulsion into space is enormous. The Vanguard rocket was engineered to burn about eight tons of propellant to place a satellite weighing 21.5 pounds into orbit. The pay loads must be very important to justify such expenditures of fuel. But the justification may perhaps not be as extraordinary as is implied by the above figures. For example, a little reckoning to translate efficiency of space travel into homely earthbound terms shows that, in only one revolution of 25,000 miles, completed in, say, an hour and a half, the mileage per pound of fuel comes to more than one and a half. In a 24-hour day of 16 revolutions and 400,000 miles, the return comes to 25 miles per pound, or more than 200 miles per gallon. Should the satellite stay up for a year, the mileage would amout to more than 9,000 miles per pound of fuel. These approximate figures, applied generally to reckoning the fuel needs of orbiting vehicles large enough to carry men, hint at quite economical interplanetary travel in terms of energy consumption per unit of distance covered.

Project Vanguard illustrates a few of the complexities surrounding such a venture. (The data for Vanguard-type launchings has already become obsolete. However, such detailed information may be very difficult to obtain on future projects.)

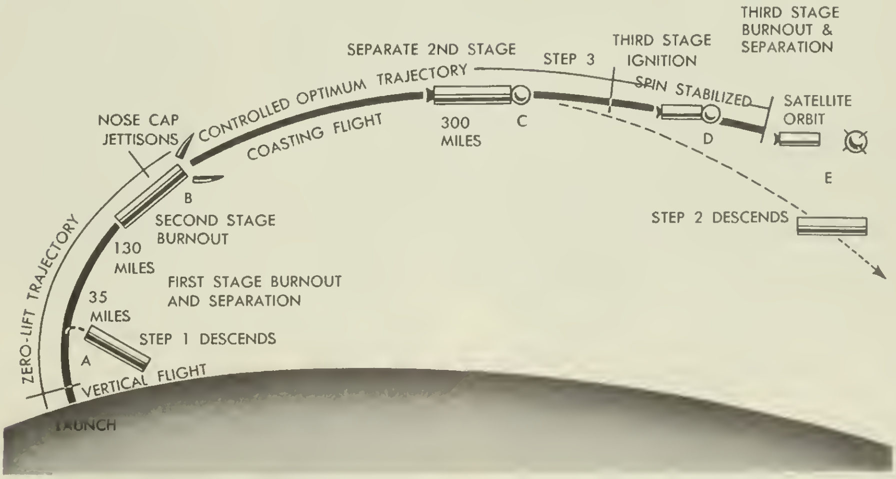
Courtesy of Martin Company

▲ A model of the 6.4-inch, four-pound "Vanguard" satellite that went into orbit March 17, 1958. The power to transmit "beeps" back to the earth is furnished by solar powered batteries which harness the sun's rays through small windows.

The fuel for the first rocket stage is kerosene and liquid oxygen, the second uses white fuming nitric acid and unsymmetrical dimethylhydrazine, and the third uses a solid propellant.

The accompanying diagram illustrates other launching data. Notice that the device begins its curve into path of orbit as early as the first stage. At about 130 miles altitude the second stage burns out, but this

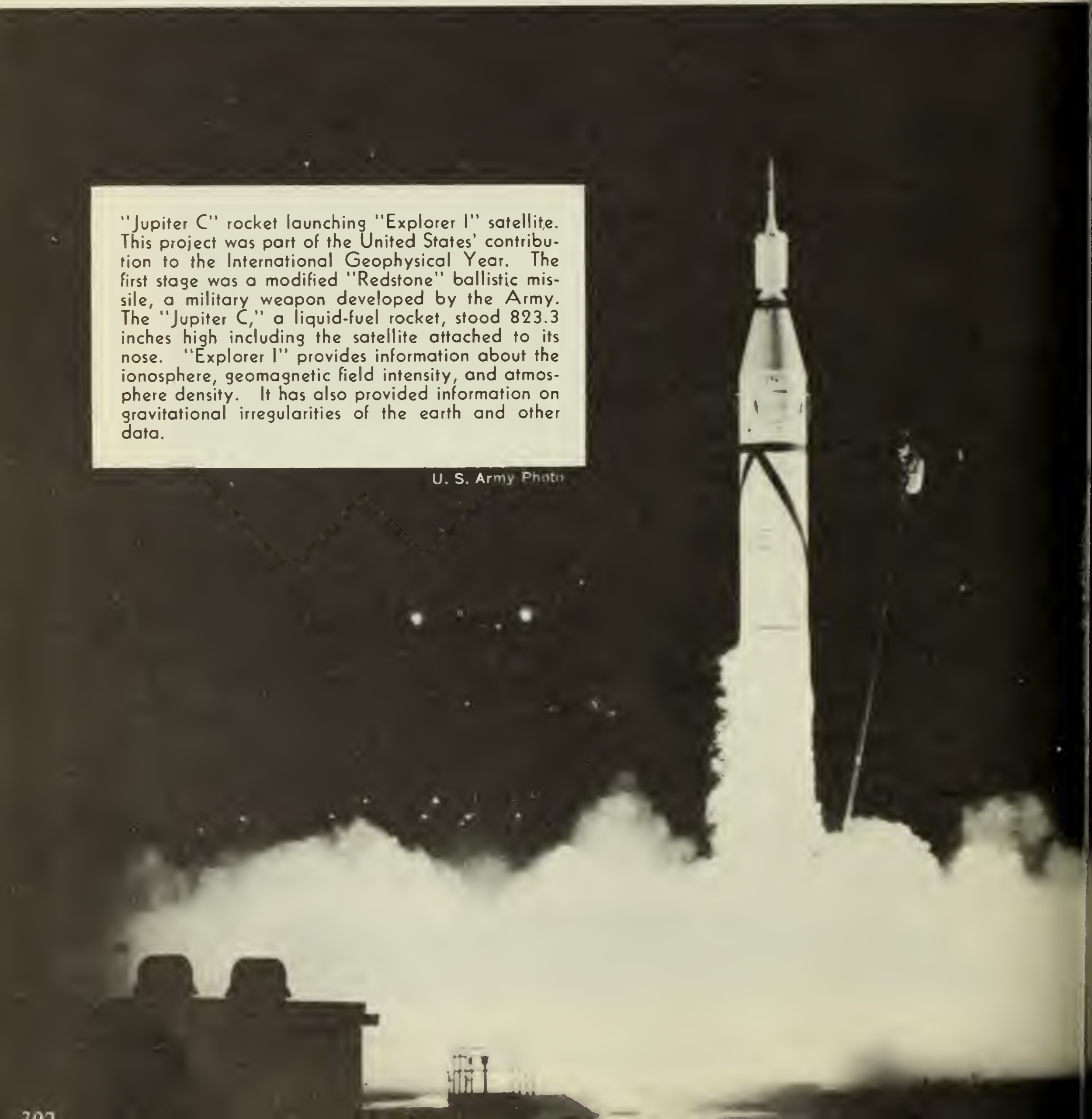
Based on Berganstand Beller, Satellite and Spaceflight



Launching technique for 21.5-pound "Vanguard" satellite. The launching process takes only ten minutes and covers 1,500 miles.

stage remains a part of the structure (except for the discarded nose cone) in a long coast to the apogee of its ballistic path. By that time, the turn to approximately horizontal to the earth's surface has been completed. Then, about 700 earth surface miles from take-off, auxiliary rockets spin the third stage and slow the second stage. The latter begins to drop. By burn-out time of the third stage, 600 seconds from takeoff, the satellite is pushed free from the third stage structure, and both, separated by a little space, assume orbits at about 18,000 mph.

Directional control, either built-in or responsive to earth-originated impulses, must function within exceedingly narrow margins of error if a satellite is to be launched successfully. The last directional control, using the last bit of power, directs the vehicle into the proper path. Thereafter it is a ballistic missile in space.



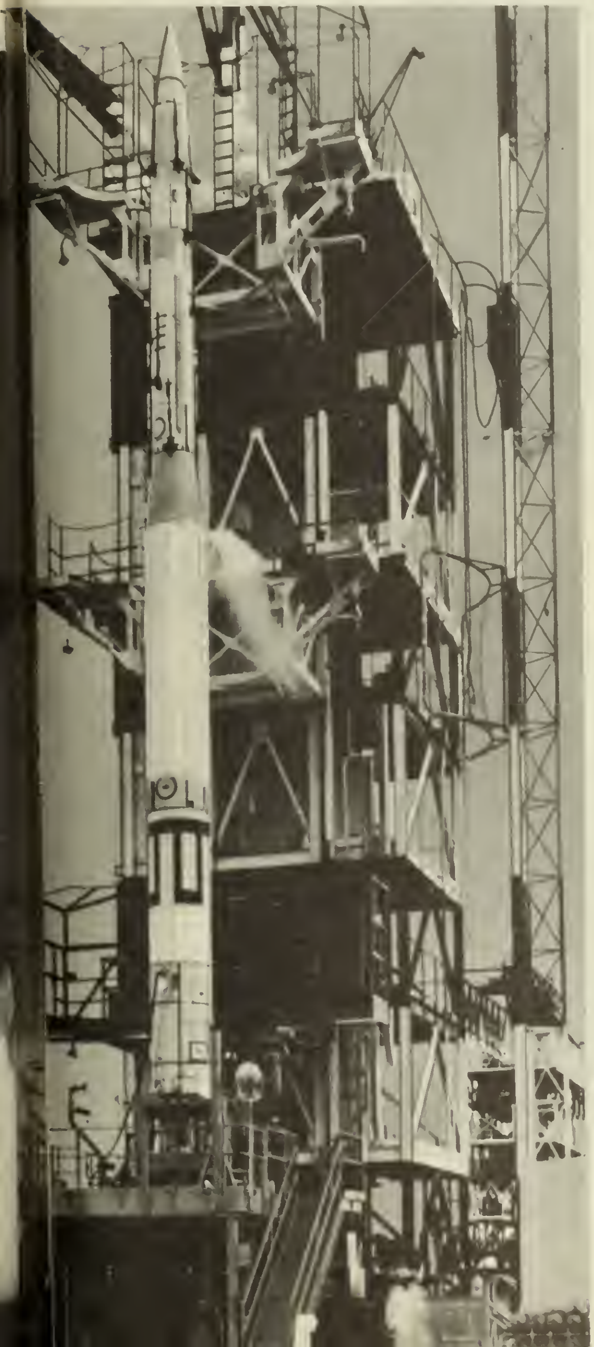
"Jupiter C" rocket launching "Explorer I" satellite. This project was part of the United States' contribution to the International Geophysical Year. The first stage was a modified "Redstone" ballistic missile, a military weapon developed by the Army. The "Jupiter C," a liquid-fuel rocket, stood 823.3 inches high including the satellite attached to its nose. "Explorer I" provides information about the ionosphere, geomagnetic field intensity, and atmosphere density. It has also provided information on gravitational irregularities of the earth and other data.

U. S. Army Photo

"Vanguard" Launching Vehicle.

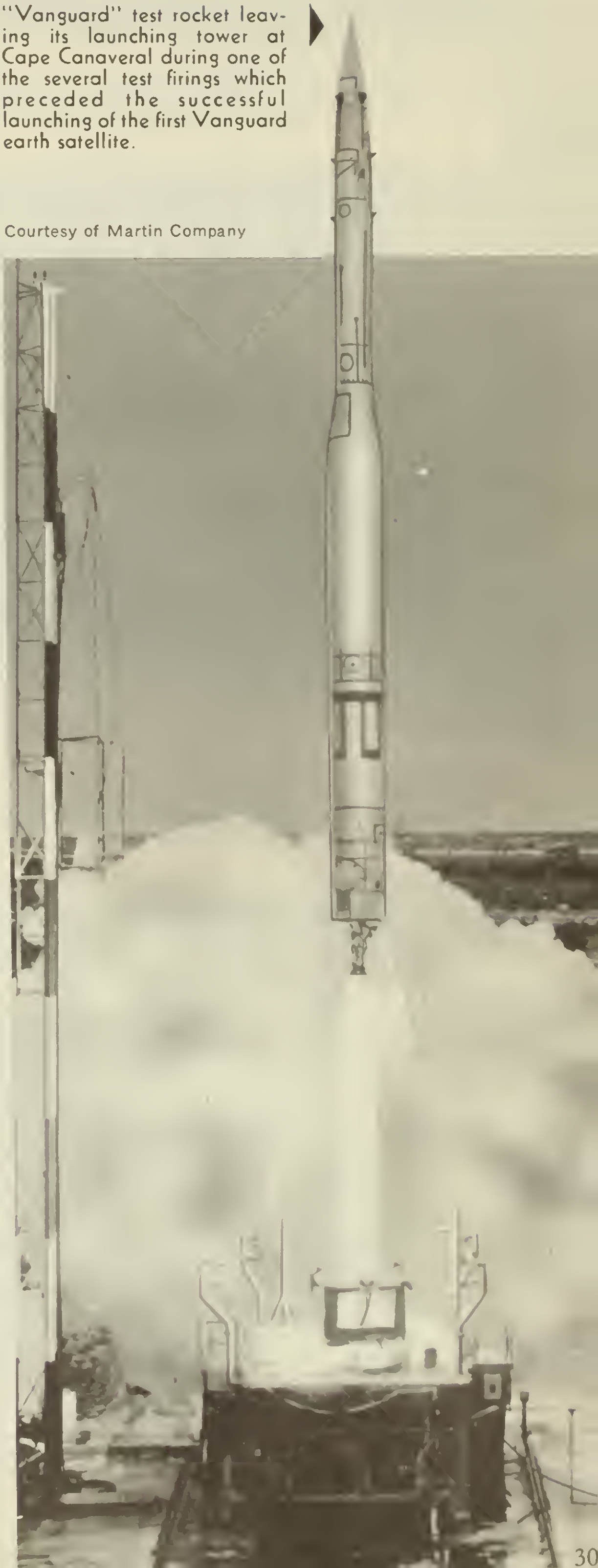
"Vanguard," the satellite launching rocket designed and built by the Martin Company, is as tall as a seven-story building. The rocket shown here is a test vehicle in its giant gantry-crane structure at Cape Canaveral, Florida. Hinged platforms of the structure close around the rocket to give easy access to various sections while it is in a vertical position. The "smoke" is caused by evaporation of liquid oxygen used as an oxidizer in the first stage.

Courtesy of Martin Company



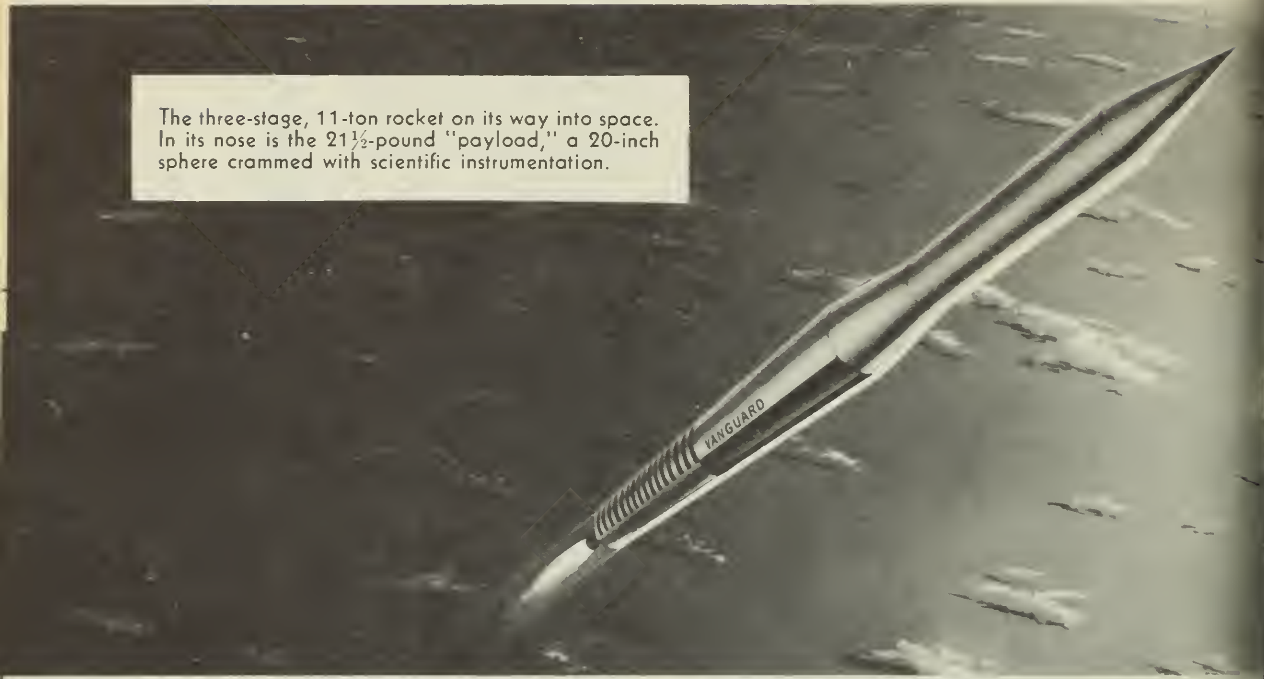
"Vanguard" test rocket leaving its launching tower at Cape Canaveral during one of the several test firings which preceded the successful launching of the first Vanguard earth satellite.

Courtesy of Martin Company

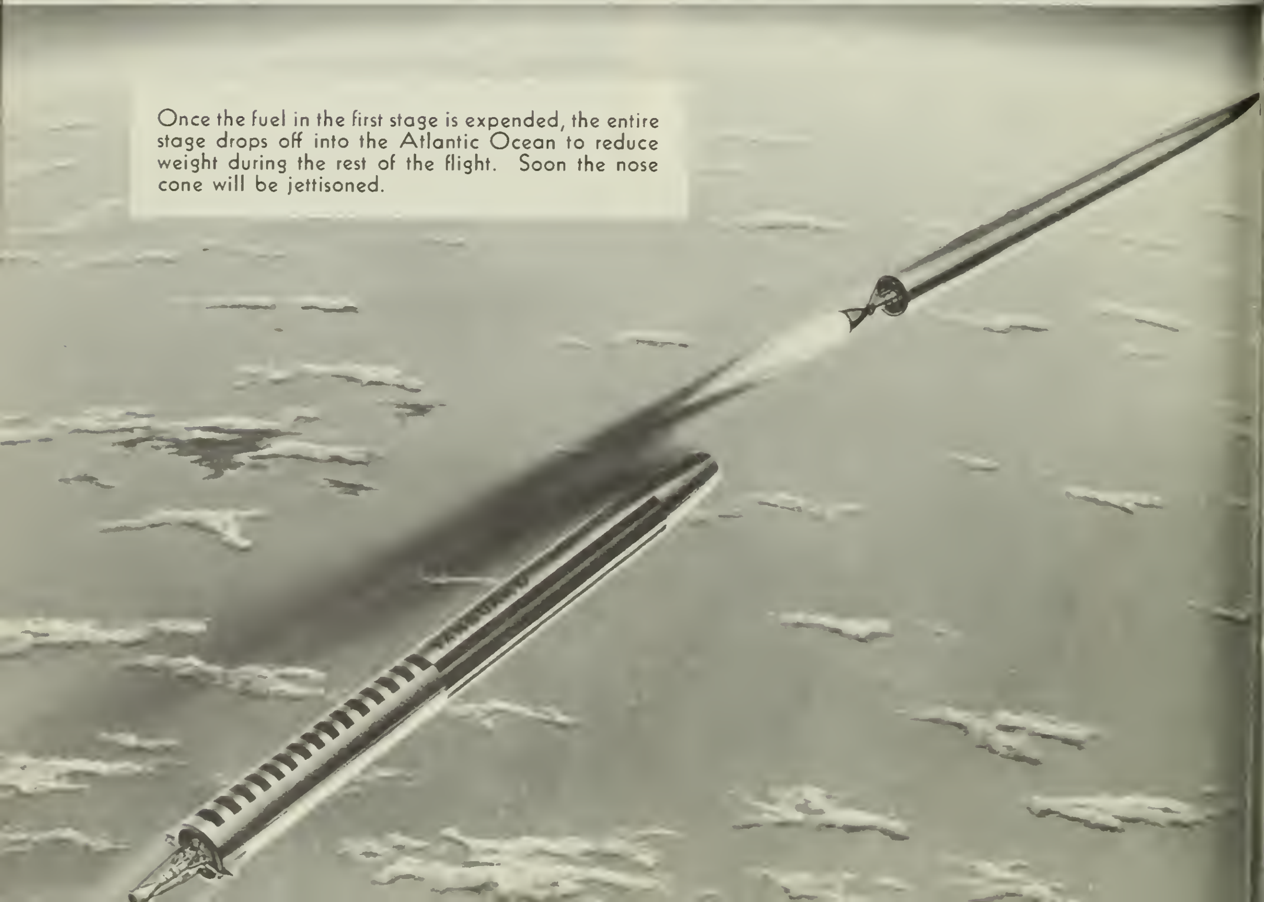


Flight of the "Vanguard" as envisioned by a Martin Company artist.

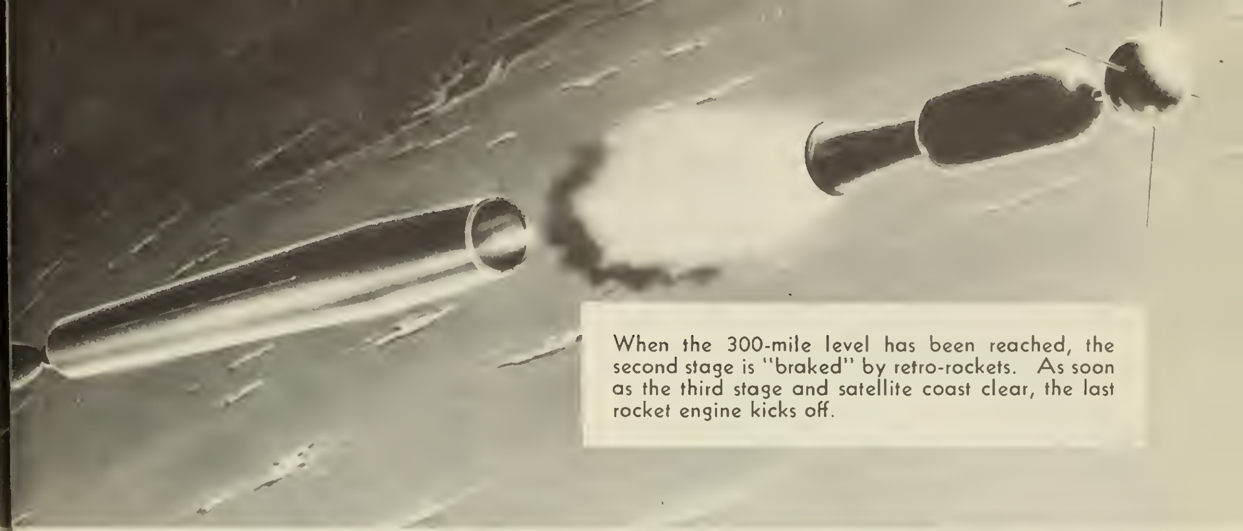
Courtesy of Martin Company



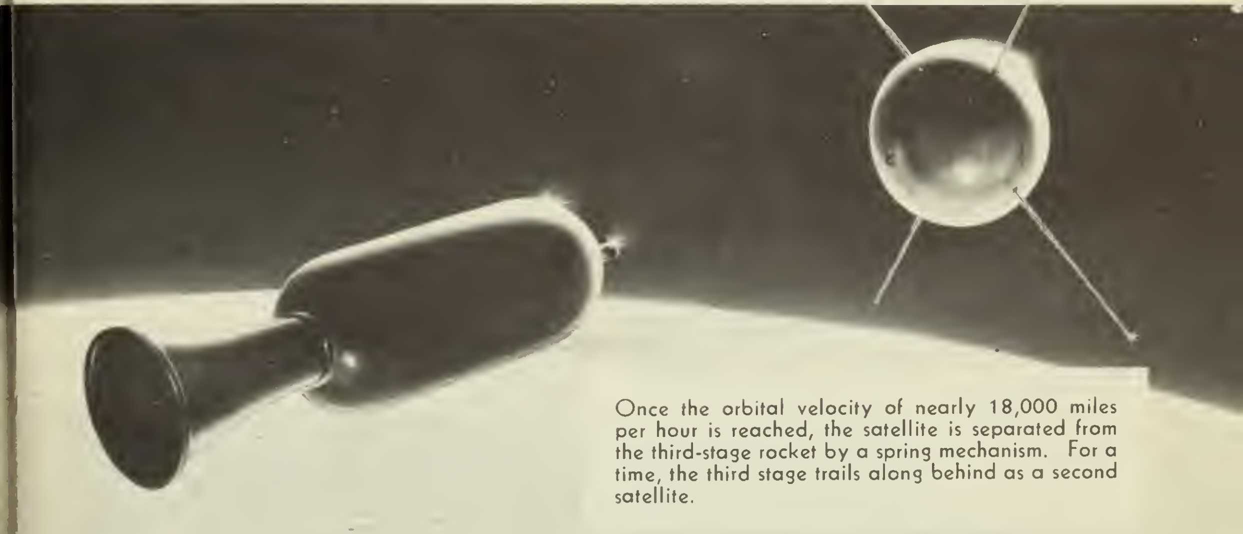
The three-stage, 11-ton rocket on its way into space. In its nose is the 21½-pound "payload," a 20-inch sphere crammed with scientific instrumentation.



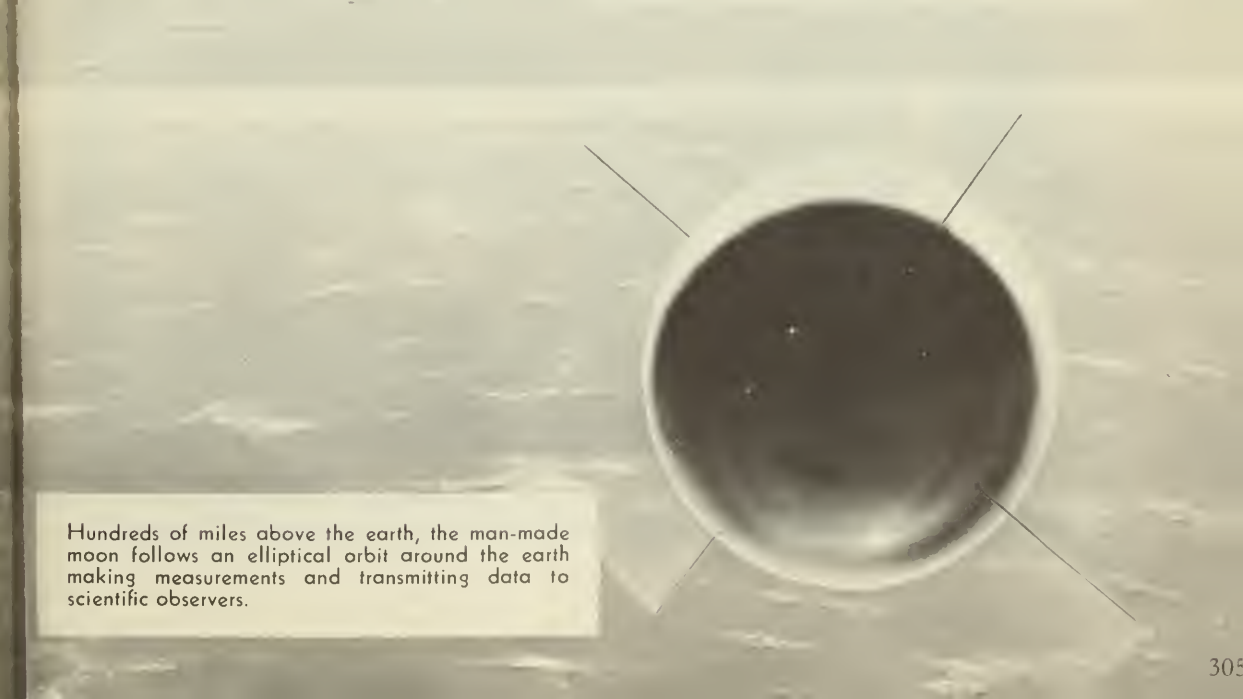
Once the fuel in the first stage is expended, the entire stage drops off into the Atlantic Ocean to reduce weight during the rest of the flight. Soon the nose cone will be jettisoned.



When the 300-mile level has been reached, the second stage is "braked" by retro-rockets. As soon as the third stage and satellite coast clear, the last rocket engine kicks off.



Once the orbital velocity of nearly 18,000 miles per hour is reached, the satellite is separated from the third-stage rocket by a spring mechanism. For a time, the third stage trails along behind as a second satellite.



Hundreds of miles above the earth, the man-made moon follows an elliptical orbit around the earth making measurements and transmitting data to scientific observers.

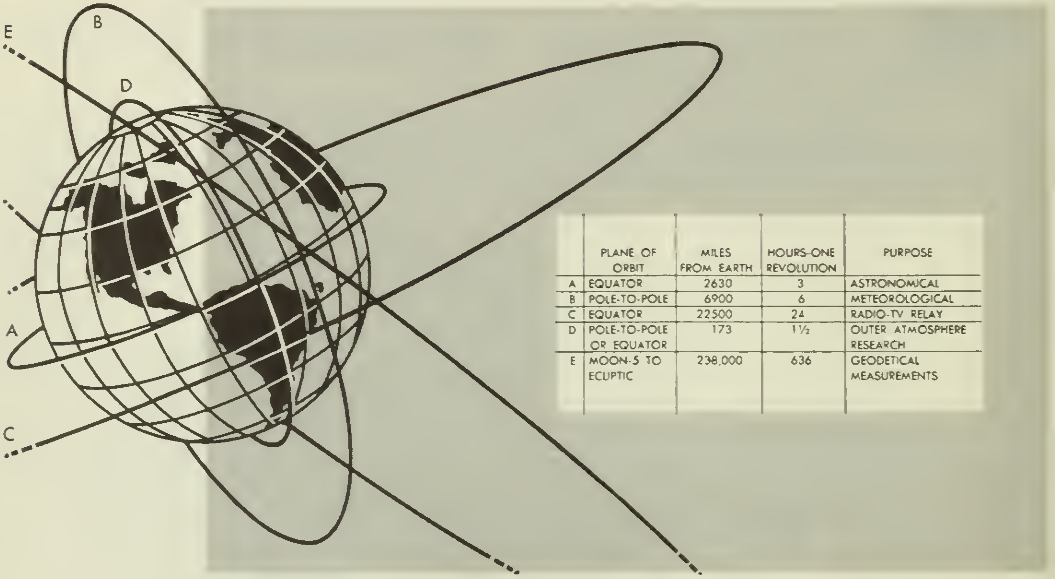
Uses of Artificial Satellites and Space Platforms

Relatively permanent bodies in the heavens which can be made to support instruments or men have certain obvious advantages over ephemeral rockets or high-altitude balloons or aircraft. Repeated or continuous monitoring of cosmic rays from outer space, and of x-rays, ultraviolet, and radio waves from the sun, will yield data of great scientific significance. For example, electromagnetic energy originating in the sun is suspected of influencing earth weather. Also, it is established that the sun's radiations influence radio and wire communication at times. From the vantage point of a station in outer space, the surface of the earth may be photographed; more detail of earthly shapes will be available to cartographers. This, plus data in relation to mass gravitational forces, will also be used to get better information concerning the exact distance between points on the earth's surface—information which is of great importance in precise navigation, map making, and pin-pointing targets for intercontinental ballistic missiles. Precise gravitational measurements will also aid in determining the thickness of the earth's crust. Perhaps movements of tides which are known to occur in molten masses beneath the crust may be charted.

Microphones and erosion gauges will be able to measure the frequency and size of small meteors and cosmic dust particles during both "normal" times and when the earth is in the vicinity of comets and other clouds of sky matter. This information will be useful for planning future manned flights. Almost all of this information can be transmitted to earth observers by means of tiny telemetering instruments.

Space platforms may include artificial and natural satellites, such as the moon and asteroids (asteroids are rocks of only several miles in diameter orbiting the earth) and even artificial islands suspended in the area where the earth's and the moon's gravitational fields balance each other. They will provide unique laboratory conditions of vacuum, radiation, gravity, etc., unavailable here on earth.

Some believe that it may eventually be possible to populate the moon. Such popu-



	PLANE OF ORBIT	MILES FROM EARTH	HOURS-ONE REVOLUTION	PURPOSE
A	EQUATOR	2630	3	ASTRONOMICAL
B	POLE-TO-POLE	6900	6	METEOROLOGICAL
C	EQUATOR	22500	24	RADIO-TV RELAY
D	POLE-TO-POLE OR EQUATOR	173	1½	OUTER ATMOSPHERE RESEARCH
E	MOON-5 TO ECLIPTIC	238,000	636	GEODETICAL MEASUREMENTS

Courtesy of Martin Company

Some of the useful satellite orbits believed to be within the reach of present day technology.

lations would live in pods or domes on the surface, or in subsurface spaces, both capable of holding an atmosphere. The moon is believed to be a logical place to serve as a jumping-off platform for interplanetary travel, because here could be marshalled, in the absence of a fuel-wasting atmosphere, the machines and fuels necessary for such an arduous undertaking. Furthermore, the escape velocity of the moon is only 5,400 mph. This fuel saving factor alone would make it a desirable launching site.

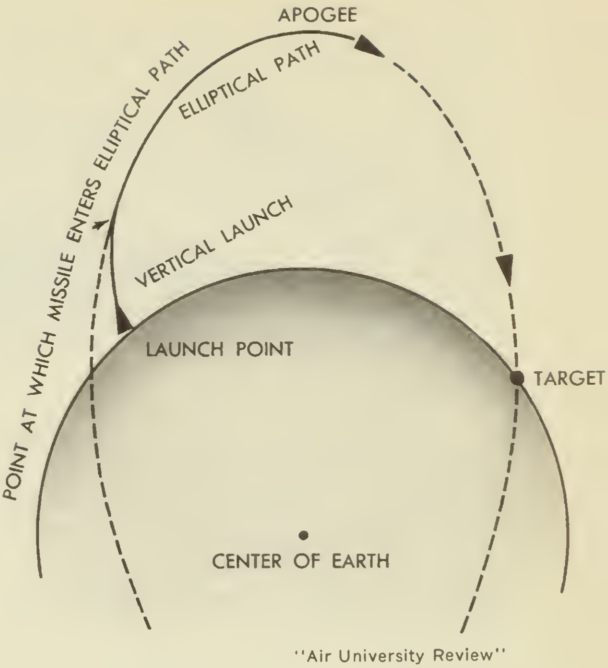
INTERCONTINENTAL BALLISTIC MISSILES (ICBM)

If, at the moment of power cut-off during the launching procedures, the satellite's direction is pointed too high or too low in relation to the horizontal, it will assume an orbit so eccentric that its perigree will be within the earth's atmosphere. Such an orbit would also result if the vehicle's velocity at thrust cut-off were too slow. In that event, the elliptical path of the missile might intersect the surface of the earth. Engineered to do this, with controls suitably adjusted to cause the first intersection to occur at a predetermined spot, and equipped with a warhead, it becomes an intercontinental ballistic missile.

While the ICBM launching vehicle is essentially the same in many respects as a satellite launcher, the multiplicity of variants encountered in its successful development and use make the successful ICBM considerably more difficult of achievement than the successful earth satellite. The margins of permitted error are even smaller if a reasonably small target is to be hit, even with a nuclear warhead.

ICBM Trajectories

The nose cone of an ICBM may be compared to an extremely long range artillery projectile carrying a high-explosive, nuclear, or thermonuclear device. Like an artillery shell, it follows an elliptical (or parabolic) trajectory. Since the artillery shell cannot be controlled in flight, the total amount of control that the artilleryman has over the trajectory of the shell is determined within the gun—by the amount of explosive charge and by aiming the barrel.

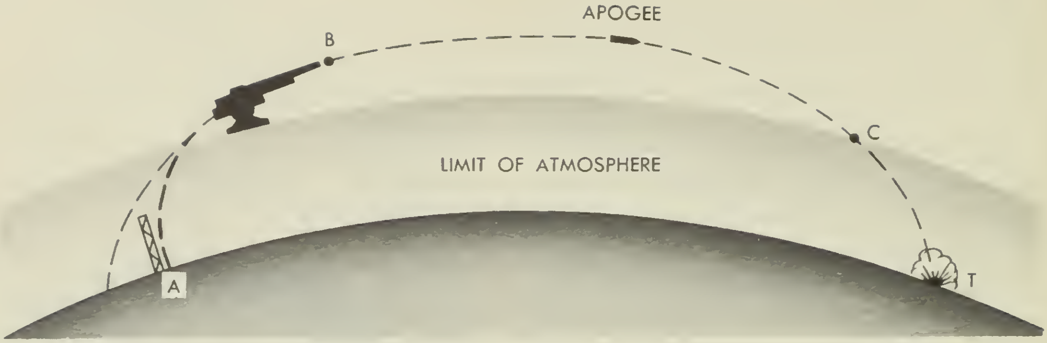


"Air University Review"

Ballistic missile trajectory.

Suppose for a moment that we have such a gun, capable of firing a shell over 5,000 miles, and that we place it at a point B in space. We make our calculations of muzzle velocity, range, direction and so on, and fire the shell. We know it will follow a trajectory up into space, and then down onto the target.

The problem, of course, is that we have no such gun, and could not station it at point B if we had it. So it is the job of the ICBM designer to produce a missile which can be launched from point A on the ground, and guided with such accuracy that it will leave point B at the proper velocity and pointed in the right direction. Power is applied to an ICBM only during the initial portion of its flight, that is, from A, the *launch point*, to B, *the thrust cut-off*. All necessary guidance and control of the missile must be accomplished during the powered flight, for the missile motion cannot be in-



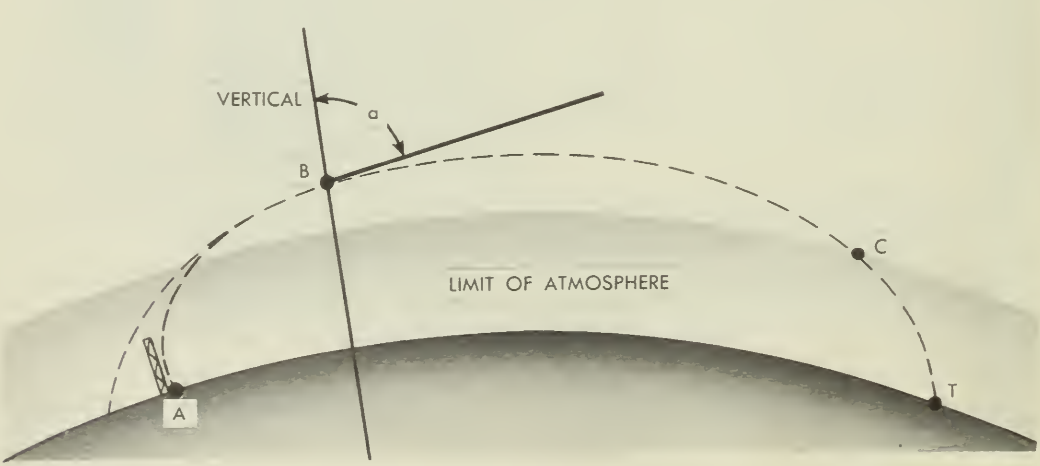
fluenced when power is no longer available.

This task is equivalent, then, to guiding the projectile through an imaginary (but correctly aimed) gun barrel at point B, at exactly the "muzzle velocity" required to give it the correct range. How difficult this is will become apparent as we proceed.

The ICBM is launched straight up. This simplifies the launcher required for such a large vehicle and also shortens the time that it is close to the ground during take-off. After its initial vertical climb, the vehicle makes a planned turn toward the thrust cut-off point. During this turn, the guidance system begins to function and continues to do so until the missile reaches the required velocity, altitude, and "aiming" angle. At this point (point B), it automatically cuts off the propulsion system.

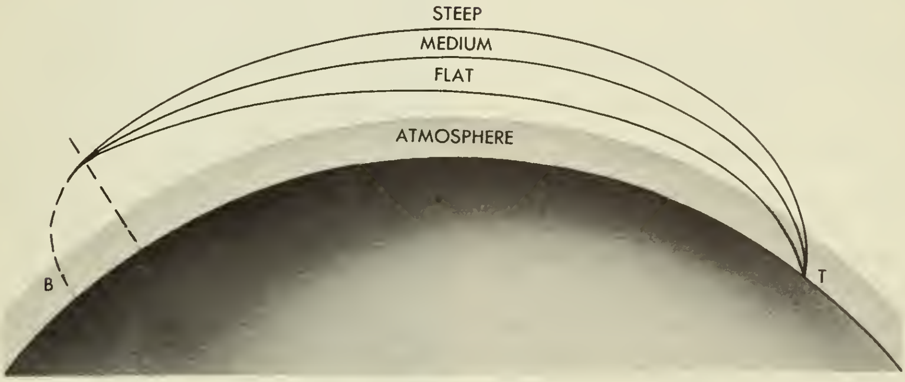
The power requirements for an ICBM are quite large and the engines constitute a considerable weight. Of course, the missile gets lighter as fuel is consumed, but it is advantageous to get rid of the empty tanks as well. As with satellite launchings, ICBM are projected by staged rockets. When the first stage rocket has used its fuel, it is detached and dropped. The second stage is then started, and it propels the missile on toward B. As the missile approaches B, the engines on the second stage are shut down, and the final adjustment of direction and velocity is accomplished with small rockets called *vernier engines*. These, finally, are shut down just as the missile passes B.

The trajectory beyond the thrust-cutoff point B may be divided into two segments; the free-flight portion, from B to the point of re-entry into the atmosphere (point C):



and the re-entry portion, from C to the target. For a long-range missile the free flight portion from B to C is above the sensible atmosphere; hence the missile during this phase is a freely falling body, the only forces acting on it being its own momentum and gravitational attraction. During the re-entry portion from C to T, aerodynamic forces—primarily friction—also come into play, and these slow the missile and cause it to become heated.

The length and shape of the free-flight trajectory are determined by the speed of the missile at thrust cutoff, the angle between the local vertical at B and the missile's direction of travel (angle *a*), the altitude of point B, and the values of the downward acceleration due to gravity along the trajectory.



There are many sets of values for velocity, angle, and the spacial position of point B that will put the missile on a trajectory to the target, but some sets are mor[illegible] than others in respect to the amount of [illegible] pellant required or the precision [illegible]

Considering a given point B and a given target T, one finds that for every thrust-cutoff speed between the lowest and the highest values needed to reach the target, there are two values of the climb angle at B that yield trajectories connecting B and T. One of these trajectories is steep, of high apogee; the other is flat, of low apogee. If we try lower and lower thrust cutoff speeds, we find that the two possible trajectories for each speed begin to approach each other, the steeper trajectory becoming flatter, and the flatter trajectory more arched.

Finally, when we use the minimum cutoff speed at which the missile will reach the target, the two possible trajectories merge into a single one of medium height. Because this medium trajectory requires the lowest cutoff speed, it is the trajectory that requires the least fuel to establish. The medium trajectory is also more favorable in other respects. For a steep trajectory the re-entry speed is high, thus presenting a more formidable heating problem. For a flat trajectory, the re-entry path through the atmosphere is long. Both very steep and very flat trajectories require a more precise guidance system than the medium trajectory.

The determination of the correct trajectory for such long flights is complicated by many factors. One of these is that the earth does not stand still, but rotates on its axis.

When it leaves the thrust cutoff point, the missile must not be pointed at the location of the target at that moment, but at the point the target will have rotated to during the missile's time of flight. A missile flying due west must therefore have a shorter trajectory than the actual land-measured distance, and a missile whose trajectory lies across the North Pole must be aimed at a point somewhat east of the target.

The earth's rotation also imparts an eastward velocity to the missile at the time of launching. The thrust of its engines directs the missile straight up, but the earth's spinning throws the missile toward the east. This is an advantage when firing a missile eastward, but a disadvantage when firing it westward. Nor are these the only complications. In aiming long-distance missiles which travel through space to targets on earth, the calculations must allow for differences in the force of gravity at different places. These differences occur because the earth is not a true sphere and because it is neither smooth nor of consistent density. The trajectory is directly affected by these differences.

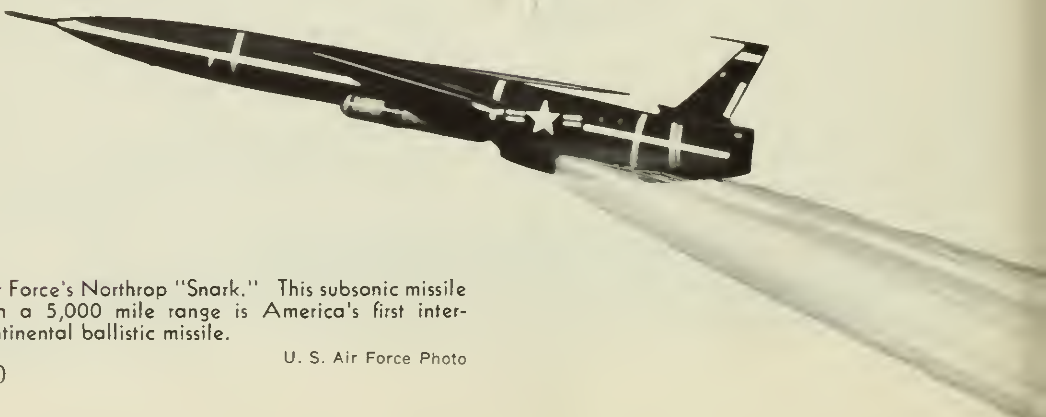
Further complications arise from the fact that the moon's gravitational field affects objects on earth. Just as it causes ocean tides, it causes tides of the atmosphere. The atmosphere is therefore thicker when the moon is overhead. Furthermore, a missile fired when the moon is overhead is measurably lighter in weight than one fired when the moon is on the opposite side of the earth.

ICBM Controls and Guidance

A ballistic missile is dependent on its control system for maintenance of a stable attitude, especially in the low-speed portion of the trajectory immediately after take-off. The control system must prevent the missile from going off course during and after any disturbance, such as a gust of wind, and must prevent wobbling in attitude after a guidance command. Because it is difficult to maintain sufficiently tight control without making the missile unstable, a significant portion of the control system engineering must be concerned with how the missile is affected by airframe vibration, propellant sloshing in the tanks, and so forth. "Solving the control problem", says one expert, "is somewhat like trying to balance a four-foot length of garden hose on its end."

In radio-inertial or radar-command guidance, measurement of the position and velocity of the missile is performed by one or more ground-based radars, and corrective maneuvers are computed by a ground-based computer and transmitted to the missile as "commands." Inertial elements, such as gyroscopes, may also be included in the missile, their purposes being to keep it approximately on course during any temporary loss of ground guidance and to prevent impact on friendly territory in case of complete loss of ground guidance. However, precision guidance is obtained primarily from the ground.

When tracking radar is used for guidance of an ICBM, or for evaluation of the guidance system, an error in apparent direction of the missile can be produced by refraction of the micro-waves in clouds. This problem is under experimental and theoretical investigation, as is the problem resulting from the fact that at high altitudes the exhaust flame from the rocket engines spreads to a large angle. When radio communication between the missile and the ground is necessary, the transmission path may be through the flame, and the ionization of the gases in the flame may attenuate and refract sig- [illegible] such an extent that reception will be



Air Force's Northrop "Snark." This subsonic missile with a 5,000 mile range is America's first intercontinental ballistic missile.

U. S. Air Force Photo

Boeing "Bomarc" long-range supersonic missile, designed to intercept enemy aircraft and missiles while they are still far from American borders. The "Bomarc" uses rocket power for take-off and ramjet power for cruising.

difficult. A similar problem arises when the missile goes above the ionosphere. This layer of charged atmospheric particles also reflects and refracts radio control and tracking signals, especially in the daytime.

Construction Problems

The design of any airframe involves a continual struggle and compromise in satisfying requirements of both weight and strength. For a long-range ballistic missile, as for test and satellite rockets, which must be power-accelerated all the way to thrust cutoff, excess weight is a critical problem, for it results in a drastic reduction of maximum range. Yet the airframes must have sufficient strength and rigidity to support the other components and the propellants without failing under normal loads at rest or in flight. Included in these loads are the stresess caused by vibrations of the engines, propellant sloshing, directional maneuvers, and aerodynamic heating.

One effect which must be allowed for is the shift of the center of gravity of the vehicle as the propellant is consumed. The relative positions of center of gravity and point of application of the thrust force are a determining factor in missile stability. In a multistage vehicle problems of stability arise because of the rapid change in the position of both the center of gravity and the "center of pressure" (thrust application point) when a stage with its rocket engines is jettisoned and the next stage begins to operate.

Re-entry

The nose cone of an ICBM contains, among other things, a nuclear warhead and provision for arming and fuzing. On returning to the earth through the atmosphere the nose cone should be decelerated to reduce the possibility of burning up from aerodynamic heating. It must be contoured for the required deceleration and for minimizing turbulence over its surface, and it must be constructed of the best heat-resistant materials which can be developed.

Several independent lines of evidence

have yielded approximate values for the probability of a collision between an ICBM and a meteoric particle and for the probable value of the meteoric mass encountered. For a single flight there appears to be about an even chance of collision with a particle of diameter as large as 0.0001 inch. If the vehicle should encounter a meteor shower, the collision chances would be larger, though still so small that the vehicle's course and range would not be affected appreciably. The damage would be confined to abrasion and pitting of the vehicle's skin. Such damage can also be produced by encounters with atmospheric dust during the initial and final portions of the flight. Pitting of the skin conceivably could result in abnormal heating during passage through the atmosphere, which can create some problems. As for the chance of collision with a meteor sufficiently massive to wreck the missile or knock it seriously off course, this turns out to be so exceedingly small that it can be ignored.

The warhead uses of an ICBM are obvious. Other uses may ultimately include intercontinental exchanges of high priority freight and passengers. The chief difficulties to be surmounted for such uses, once techniques have been perfected to permit safe descents, include development of cheaper and more plentiful fuels.

MANNED SPACE VEHICLES

The first steps in man's space travels will probably be in satelloids, then in earth satellites, and then in vehicles to the moon.

The satelloid is a craft which flies in the atmosphere, is ballistic or orbital in space, and returns to earth as a powered glider. One such craft is the North American X–15. Speeds of 4,000 to 5,000 mph and a service ceiling of 100 miles have been mentioned for the X–15. It is not a true satelloid, for a true satelloid must be capable of circling the globe at least once, but it is the first step.

The X–15 and the satelloids which will follow it symbolize the fact that aeronautics and astronautics are but two aspects of the single phenomenon: human flight. They will use rocket propulsion. Wings and conventional control surfaces will not disappear but will be supplanted by small rockets for use in space where rudders and ailerons have no effect.

They may be launched from high-flying "mother" aircraft, from balloons, or as the last stage of a multistage rocket. Their speed will be shown on cockpit instruments which read in Mach numbers, in per cent of orbital speed, and perhaps in angular velocity relative to earth.

Indications are that satelloids will look very much like modern supersonic aircraft such as the X–3 or the F–104. Their shape will be irrelevant in space and so will be determined almost entirely by aerodynamic considerations.

Insulated, pressure-sealed, detachable crew compartments will be used. Such cabins have already been tested on balloons and in the Bell X–2.

On the ground, simulated space-vehicle environments have already undergone tests with men inside. Not the least hazard during long trips in ultraconfined spaces is the psychological effect upon men, particularly if they have to contend with weightlessness. However, it now appears that if an earthly atmosphere at approximately earthly pressures and temperatures can be maintained, living passengers can survive.

Within just a short time closed living quarters become intolerable because of mounting percentages of the chief waste product of breathing beings—carbon dioxide. More than five percent is intolerable, and this concentration occurs long before the oxygen content falls from the normal 21 percent to a danger point of 12 percent. Effects from other body wastes ultimately become dangerous as well, and in lengthy space travel, such as to planets, a balancing system must be provided in a manner analogous to the balanced aquarium in which fish are kept. Perhaps a tank of

The Douglas X-3.

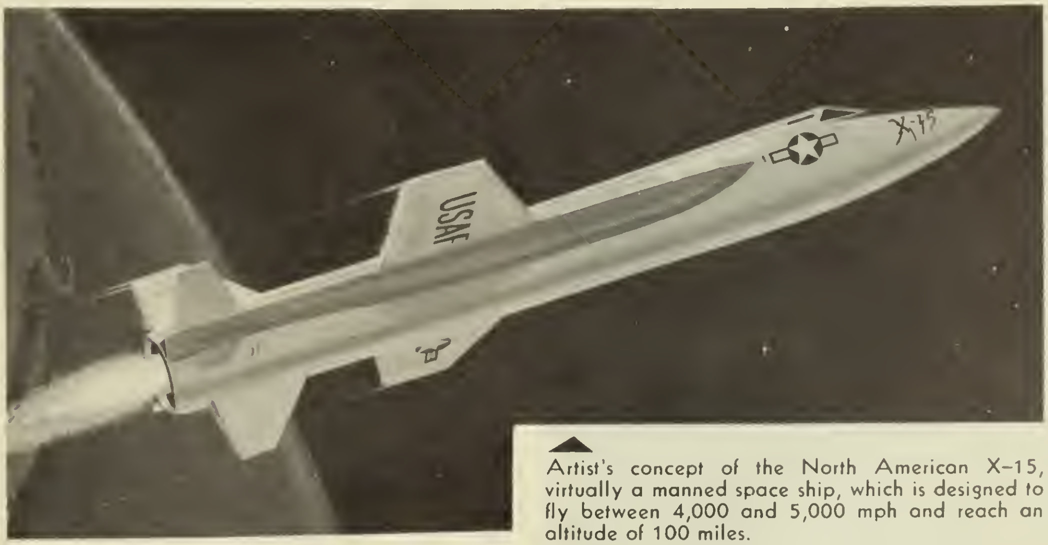
U. S. Air Force Photo

algae can ultimately be developed in which, by photosynthesis (use of sunlight), carbon dioxide can be converted to its component parts. In a completely balanced system for use in interplanetary travel, all materials would be converted or salvaged and used over and over again.

Sustenance, and protection from too drastic acceleration and deceleration forces, are the next problems. The latter two can kill suddenly, and these conditions may be encountered not only in ascending and descending, but in turns and spins. Descent through an atmosphere, as on earth, brings with it the danger of overheating; while deceleration and descent onto an atmosphereless mass such as the moon must be particularly smooth. Adequate built-in capability for safe return from such a place as the moon means that enough fuel must be carried to accomplish this as well as fuel for deceleration at both ends of the journey, and sufficient food to insure that passengers do not starve to death.

Propulsion in Space

So far, the only practical principle for propulsion in space seems to be the same action-reaction principle used in present aircraft and missiles. The accelerations required in a useful space vehicle can be achieved in the same way. You will recall that thrust can be increased by increasing the mass shoved backward per second, and that this can be achieved in two ways:



▲
Artist's concept of the North American X–15, virtually a manned space ship, which is designed to fly between 4,000 and 5,000 mph and reach an altitude of 100 miles.

Drawing based on material from Air Force Magazine

▲ U. S. Air Force Photo

High-altitude MC–4 partial pressure suit. The airman is in a pressure chamber during a simulated high altitude training flight.

Designed initially for pilots who will fly the North American X–15, the XNC–2 space suit shown here will permit airmen to fly efficiently at extreme altitudes.

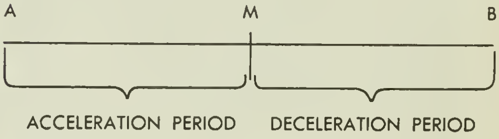
▼ U. S. Air Force Photo

shoving a lot of mass backward at a lesser velocity, or shoving a smaller mass backward at a greater velocity.

It turns out that, in order to keep total ship weights as low as possible, it is better to use as light a fuel as possible and eject it at the maximum possible velocity. Such an arrangement calls for low-weight fuels but very high power and energy requirements, as well as heat resistant jet nozzles.

Vehicles which are confined to the atmosphere and can depend upon the gravitational force of the earth have no serious problems of deceleration. A missile can stop simply by falling and crashing into the earth. A conventional aircraft or a descending satelloid can waste away its velocity by relying on aerodynamic drag or by cutting power and nosing up to let gravity oppose its forward momentum.

A space ship cannot rely on these techniques. Consider a theoretical space vehicle going from A to B in gravity-free space. If it starts from rest at A, and wishes to go to B in the shortest time, it will accelerate at the maximum rate its equipment and crew can stand until it reaches the mid-point of its journey. At this point, it will have to reverse its engines, and if the ship is to come to a stop at B, the deceleration rate will have to be exactly the same as the acceleration was. It therefore requires the same amount of work to slow the ship to a stop that it took to bring it to the mid-point.

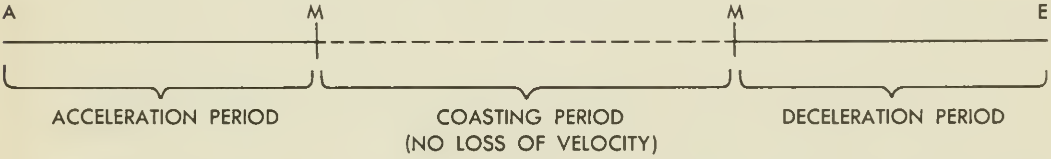


The foregoing would not be precisely true in practice. The ship at mid-point is lighter than when it started because mass has been ejected from it, but if the mass of fuel consumed is small compared to the mass of the vehicle, the difference will not be great.

As an example of the power requirements, consider a vehicle of 100 tons weight (about the size of a DC–8), to be propelled by an ionic rocket at an acceleration of 1 *g*, with a total reaction mass of 10 tons.[1] At a flow of one kilogram (2.2 pounds) per second, the power output required will be 700,000,000 horsepower. Such a ship will possess almost three hours acceleration capability.

Accelerating from "rest" in space, this ship could reach a speed of 35 miles per second and still have sufficient reserve mass to decelerate again to rest. The total energy required to exhaust the reaction mass is equivalent to 25 pounds of Uranium 238 at full efficiency.

Having reached a speed of 35 miles per second, the engines may be shut down and the vehicle will proceed, coasting, at 35 miles per second for as long a time and distance as required. In essence, insofar as propulsion problems alone are concerned, the midpoint of the journey (point M) can be considered to stretch out as far as is desired. The deceleration phase of the journey can be postponed until a point is reached which is about as far from the destination as the thrust cut-off point was fróm the departure point.



Of course, there is no such thing as gravity-free space. The gravitational fields of stars, planets, and space ships themselves are inextricably intertwined in all space. However slight their effects may be at some points in space, they will influence a space ship's path. They can therefore be counted on to assist as well as complicate astronautical adventures.

The Implications for the Future

Contemplation of space travel opens almost infinite realms for speculation. The military implications are obvious. Mastery of space by any nation would be a powerful factor in establishing domination of other nations. Space platforms, whether artificial or the moon, may provide the launching sites for known weapons or destructive agents not yet invented. Some scientists say that the ICBM will be effective enough without help from a satellite, but only time will tell.

Peaceful exploitation of space capabilities may lead mankind into a fantastic future, for the scientific knowledge which can be gathered only in outer space will be an invaluable addition to our understanding and perhaps eventual control of the natural forces of weather and climate, of gravity, of the power of the atom and cosmic rays, and many other mysteries of the universe.

The invention of the steam engine resulted in vast sociological and political changes. The electric generator and light changed the world's daily routine of living. The automobile has changed urban geography and forced a revolution in the business of retailing. The airplane has shrunk the earth to a tiny ball only a few hours in circumference. Imagine now, if you can, what will be the effect of the satellites, the satelloids, and flight into outer space. Only a hint or two can be seen today, but the thought that man's destiny lies in the stars may be more than poetic fancy.

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[1] The *reaction mass* is the mass which will be thrown out the back to propel the ship forward. It is equivalent to the exhaust gas of a conventional rocket. The ship described here was hypothesized by Dr. Peter A. Castruccio in an article in *Missiles and Rockets,* June 1957. The data are used with special permission.

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